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Aerial Reconnaissance of Hazardous Substances Spills and Spill-Threat Conditions

Lockheed Electronics Co, Inc, Las Vegas, NV Remote Sensing Lab

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16. ABSTRACT
The U.S. Environmental Protection Agency's Environmental Monitoring and Support Laboratory in Las Vegas, Nevada, conducted aerial reconnaissance over a number of industrial facilities engaged in the production, storage, and handling of hazardous substances that are located near navigable waters of the United States. The purpose of this project was to demonstrate that aerial reconnaissance procedures currently utilized in monitoring oil production, refining, and storage facilities can be applied to monitoring chemical production and storage facilities to show whether spills and spill-threat conditions exist within chemical production and storage facilities, and to provide annotated photographic examples of spill conditions. Typical in-plant facilities covered in this reconnaissance include: (1) product storage facilities, including storage and holding tanks, drum storage and staging areas, and dry-product stockpiles; (2) product transfer facilities, such as marine and river terminals, and tank car and truck loading racks; and (3) plant drainage and wastewater treatment facilities. The photographic examples can serve as photo interpretation keys to aid both experienced remote sensing specialists and inexperienced personnel in monitoring chemical facilities for compliance with anticipated spill prevention regulations to be issued under authority of the Federal Water Pollution Control Act (FWPCA) as amended in 1977.

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AERIAL RECONNAISSANCE OF HAZARDOUS SUBSTANCES SPILLS AND SPILL-THREAT CONDITIONS

by

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COLOR ILLUSTRATIONS REPRODUCE
IN BLACK AND WHITE

ENVIRONMENTAL MONITORING AND SUPPORT LABORATORY
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FOREWORD

Protection of the environment requires effective regulatory actions that are based on sound technical and scientific information. This information must include the quantitative description and linking of pollutant sources, transport mechanisms, interactions, and resulting effects on man and his environment. Because of the complexities involved, assessment of specific pollutants in the environment requires a total systems approach that transcends the media of air, water, and land. The Environmental Monitoring and Support Laboratory-Las Vegas contributes to the formation and enhancement of a sound, integrated monitoring data base through multidisciplinary, multimedia programs designed to:

- develop and optimize systems and strategies for monitoring pollutants and their impact on the environment
- demonstrate new monitoring systems and technologies by applying them to fulfill special monitoring needs of the Agency's operating programs

This report discusses aerial reconnaissance procedures for monitoring chemical production and storage facilities. Spill and spill-threat conditions that exist in many chemical production and storage facilities are photographically documented. The photographic examples of chemical spills and spill-threat conditions and reconnaissance procedures presented in this report can assist EPA regional offices charged with monitoring chemical facilities for compliance with anticipated spill prevention regulations to be issued under authority of the Federal Water Pollution Control Act (FWPCA) as amended in 1977.

George B. Morgan
Director
Environmental Monitoring and Support Laboratory
Las Vegas

SUMMARY

The U.S. Environmental Protection Agency's Environmental Monitoring and Support Laboratory in Las Vegas, Nevada, conducted aerial reconnaissance over a number of industrial facilities engaged in the production, storage, and handling of hazardous substances that are located near navigable waters of the United States. The purpose of this project was to demonstrate that aerial reconnaissance procedures currently utilized in monitoring oil production, refining, and storage facilities can be applied to monitoring chemical production and storage facilities to show whether spills or spill-threat conditions exist within chemical production and storage facilities, and to provide annotated photographic examples of spill conditions. Typical in-plant facilities covered in this reconnaissance include: (1) product storage facilities, including storage and holding tanks, drum storage and staging areas, and dry-product stockpiles; (2) product transfer facilities, such as marine and river terminals, and tank car and truck loading racks; and (3) plant drainage and wastewater treatment facilities. The photographic examples can serve as training aids for both experienced remote sensing specialists and inexperienced personnel engaged in monitoring chemical facilities for compliance with anticipated spill prevention regulations to be issued under authority of the Federal Water Pollution Control Act (FWPCA) as amended in 1977.

In phase 1 of the project, a survey of current literature and depositories of chemical spill history information was conducted to identify and describe those facility elements of spill prevention and containment most often related to chemical spills and spill-threat conditions that can be readily monitored from overhead.

In phase 2, aerial photography was collected and analyzed in detail, and representative examples of a wide range of spill and spill-threat conditions were selected and annotated with the analysis results for inclusion in this report. The photographic examples were selected to emphasize the critical areas within a plant most likely to be involved in spill incidents. The reconnaissance procedures used, i.e., flight parameters, camera and film types, interpretation techniques, and documentation formats, were developed and refined by the Remote Sensing Division of the Environmental Monitoring and Support Laboratory in Las Vegas for monitoring oil-related facilities.

The photography acquired for this project clearly demonstrates that spill and potential spill conditions are common occurrences in most chemical production, storage, and handling facilities. In particular, most facilities overflown had storage and holding tanks totally lacking secondary containment structures, and tank car and truck loading/unloading facilities, and marine and river terminal facilities often lacked visible means of containment should

accidental spills occur. Finally, surface drainage in a majority of facilities was inadequate to prevent major spills from escaping the plant properties and entering the natural drainage systems, including navigable waters.

Once hazardous substances spill prevention and control regulations have been put into effect, aerial reconnaissance can be effectively and economically utilized to augment the compliance monitoring efforts of the EPA regions or other regulatory agencies. An airplane can overfly a large number of facilities in a brief period of time. With a reconnaissance report in hand, spill prevention personnel can use the interpretation results to plan facility inspection itineraries. Time can be devoted primarily to those facilities with visible problems. The time required to inspect each plant can be reduced by concentrating on those areas within a plant that the photographs indicate may have spill problems. The annotated photographs can also serve as a facility map for use during inspections and as a reference base should a major spill occur in the future.

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SECTION 1

INTRODUCTION

BACKGROUND

In 1972, the Environmental Protection Agency (EPA) estimated that, from all sources, 50 billion gallons* of the Nation's water were polluted each year.[1] The proportion of this total that was attributable to hazardous substances (chemical) spills was essentially unknown. Coast Guard statistics for 1972 showed approximately 18.8 million gallons of oil and other hazardous substances reported as spilled.[2] By 1976, the volume of all reported pollutants exceeded 33.8 million gallons, of which 23.1 million gallons were classified as oil of all types. "Liquid chemicals" accounted for 2.1 million gallons of the total reported spillage.[3]

The lack of detailed information on designated hazardous substances spills is due primarily to the fact that there have been no Federal regulations that require the reporting of hazardous substances spills.[4] As a result, what little is known of the magnitude of chemical spills has been acquired primarily from the relatively small number of spill incidents that have been voluntarily reported, i.e., 296 in 1976.[3]

Nevertheless, Congress recognized the threat to the Nation's environment and public health posed by chemical spills when it enacted the Federal Water Pollution Control Act (FWPCA) Amendment of 1972. Section 311 of that act specified that the executive branch would establish a National Contingency Plan for the removal of "oil and hazardous substances" from the Nation's harbors and navigable waterways. The executive branch was also directed to:

- establish methods and procedures for removal of discharged oil and hazardous substances,
- establish the criteria for development and implementation of local and regional oil and hazardous substances removal contingency plans, and
- establish procedures, methods, and equipment and other requirements for equipment to "prevent" discharges of oil and hazardous substances from vessels and from onshore facilities, and to "contain" such discharges.[5]

The objective of the law was to eliminate the discharge of pollutants into the navigable waters in the U.S. by 1985.[6]

*British units are used because the data in the literature were reported in British rather than metric units.

Until recently, primary emphasis has been directed toward the prevention, control, and elimination of oil pollution. EPA published oil pollution prevention regulations (Title 40 CFR Part 112) in December 1973 which became effective in January 1974.[7] These regulations established procedures, methods, and equipment requirements for owners or operators of facilities engaged in drilling, producing, gathering, storing, processing, refining, transferring, distributing, or consuming oil. The primary vehicle achieving the purpose of the regulations was the requirement for the preparation and implementation of oil spill prevention control and countermeasures (SPCC) plans by owners and operators of nontransportation-related facilities with aggregate surface storage of more than 1,320 gallons and single tanks with a capacity of greater than 660 gallons.

The Clean Water Act of 1977, enacted in December of that year, extensively amended the Federal Water Pollution Control Act. Section 311 was amended to authorize "EPA to act to mitigate damages to public health and welfare resulting from discharges of nonremovable substances, and to assess the costs to dischargers."[6] In addition, cleanup liability charges were revised, and the "area of applicability" was extended beyond the contiguous zone to include "activities" under the Continental Shelf Land Act or the Deepwater Port Act of 1974.

Through 1977, regulatory emphasis has been devoted primarily to the cleanup, control, and prevention of oil discharges and spills. Regulations relating to the prevention and control of hazardous substance spills will be developed and implemented in Fiscal Year 1979 and 1980. It is anticipated that in Fiscal Year 1979 EPA will issue spill prevention regulations for hazardous substances similar to existing oil spill prevention regulations.

PURPOSE

As spill prevention and control regulations are implemented under authority of Section 311 of the FWPCA 1972 and 1977 amendments, the concurrent implementation of an effective compliance monitoring system will be essential. The potential use of remote sensing technology to implement a spill detection system was recognized by EPA's Oil and Special Material Control Division (OSMCD) in 1976 when it requested the Remote Sensing Division, Environmental Monitoring and Support Laboratory (EMSL-LV) to conduct aerial reconnaissance operations over oil production, refining, and storage facilities in several sections of the country to augment the oil SPCC compliance monitoring efforts of the individual EPA regions. With the success of this initial effort (the results of the oil SPCC reconnaissance efforts are detailed in Section 4 of this report), the OSMCD requested the Remote Sensing Division (RSD) to develop a similar approach for monitoring chemical facilities. Considering the large geographical areas encompassed by each region, the number of installations potentially involved, and the frequencies required for adequate surveillance, overhead monitoring techniques can be used to advantage. While remote sensing systems will not replace onsite investigations, they can be important tools to indicate priority areas that merit onsite evaluation.

The purpose of this project is the development of procedures and criteria (photographic examples or keys) required to employ remote sensing to locate,

identify, and analyze hazardous substance spills and potential spill conditions that may represent a threat to the environment.

OBJECTIVES

The basic objective of the project was to define, develop, and demonstrate remote sensing techniques to rapidly and economically monitor hazardous substances spill and spill-threat conditions that can be utilized by appropriate EPA staff, regional program offices, states and other government agencies participating in environmental planning and enforcement. The primary goals are to be able to:

- detect potential spill problems areas,
- characterize plant conditions with respect to maintenance and operation,
- develop criteria for monitoring and monitoring systems,
- develop criteria for optimization of followup on-site inspections of problem areas, and
- develop documentation for regulatory action.

SCOPE

The reconnaissance procedures and spill criteria (photographic examples) are restricted to in-plant, nontransportation-related facilities. In addition, primary emphasis is placed on features and conditions most frequently related to hazardous substances spills and, of necessity, those features and conditions that can be photographed from an airplane.

The project was conducted in two phases. In phase 1, a survey was conducted to determine which plant conditions or features amenable to detection by aerial remote sensing are most often responsible for or associated with spills. All facets of a chemical complex were investigated, including location and physical setting of processing, handling, storage, and disposal facilities. In addition, a review was conducted of pertinent references and depositories of chemical spill history information within EPA and other applicable environmental regulatory agencies. The results of phase 1 included a list and description of facility elements to be photographed and analyzed, the suggested sites for gathering aerial photography, and a tentative format and outline for documenting the photographic results.

Phase 2 of this project entailed collecting the required aerial photography, analyzing the film, and documenting the results. Section 4 briefly describes the oil SPCC reconnaissance program, which served as the model and test vehicle for the reconnaissance procedures detailed in Section 5. Hazardous substances spill features and conditions encountered in chemical plants and amenable to remote sensing are described in detail in Section 6. Section 7 presents the photo analysis results, which include annotated photographs of spill features and spill conditions, and descriptions of conditions seen in each photograph.

SECTION 2

CONCLUSIONS

This project clearly demonstrated that a wide range of facility features and operating conditions related to hazardous substances spills and spill-threat conditions can be recorded on color aerial film for subsequent analysis.

In the aerial photographic survey conducted for this project, nearly 100 chemical production, storage, and handling facilities were overflown. From the film analysis results, it can be concluded that, for a large majority of the facilities photographed, even the most rudimentary spill prevention and control measures are either absent or, at best, inadequate. There is a general absence of secondary containment structures (dikes or similar barriers) particularly for holding/day tanks within processing areas and drum storage areas. In addition, drainage control at most facilities is inadequate, with surface drainage bypassing waste treatment facilities. There is a general absence of spill control measures at points of product transfer, and containment of raw material/dry product stockpiles is commonly inadequate to prevent leaching and transport of these materials into nearby natural drainage systems.

The basic aerial reconnaissance procedures being conducted for ongoing oil SPCC reconnaissance support projects can be readily utilized in aerial monitoring of chemical facilities. Spill features and conditions visible to an aerial camera are generally the same for both oil and chemical facilities, notwithstanding the relative complexity of the cleanup and amelioration posed by chemical spills.

Once hazardous substances spill prevention and control regulations have been put into effect, aerial reconnaissance can be effectively and economically utilized to augment the compliance monitoring efforts of the EPA regions or other regulatory agencies. An airplane can overfly a large number of facilities in a brief period of time. Once a reconnaissance report has been completed, spill prevention personnel can use the interpretation results to plan facility inspection itineraries. Time can be devoted primarily to those facilities with visible problems. The time required to inspect each plant can be reduced by concentrating on those areas within a plant that the photographs indicate may have spill problems. The annotated photographs can also serve as a handy facility map for use during inspections and as a reference base should a major spill occur in the future.

Finally, it is apparent that aerial reconnaissance can also serve as a useful tool for industry. A company can inspect its own facilities for spill problem areas. The resulting photographs can be used as a photo-base map for planning, setting priorities, and monitoring progress of corrective measures.

SECTION 3

RECOMMENDATIONS

The procedures for conducting an aerial reconnaissance of chemical facilities were essentially the same for oil production, processing, and storage facilities. Likewise, these procedures can be applied to other industries that handle hazardous substances--principally, the user of consumer industries. Those industries that store and handle chemical substances in facilities that may be readily monitored from the air include: iron and steel, aluminum, fertilizer, pulp and paper, paint and pigments, pharmaceuticals, detergent, and textiles.

The utility of this report as a "key" for interpreting aerial photographs of hazardous substances spill and spill-threat conditions can be further enhanced for both photo interpreters and personnel responsible for regulation compliance monitoring if it is supplemented with annotated photographic examples (keys) and descriptions of spill-related conditions peculiar to the user industries listed above.

As regulatory authorities prepare pending hazardous substances spill prevention, control, and countermeasures regulations, consideration must be given to the widespread inadequacy of spill prevention and recovery features and conditions within nontransportation-related chemical processing, handling, and storage facilities, as demonstrated by the photographic examples in this report. At least minimum standards should be established for construction of secondary containment dikes, walls, or other structures for storage tanks, processing holding tanks, raw material stockpiles, and drum storage areas. Similar standards should be set for waste treatment facilities and plant drainage. Ideally, all surface drainage ditches should be integrated with the plant waste treatment system, assuring that product spillage will not directly escape the premises nor be transported via rainfall runoff beyond the premises before it can be removed or properly treated. Finally, the general absence of spill control and recovery measures at points of product transfer, including tank car and truck racks, as well as marine and river terminal facilities where spills are a common occurrence, emphasizes the need for minimum standards for prevention, control, and recovery of hazardous substances spills.

SECTION 4

AERIAL RECONNAISSANCE IN SUPPORT OF OIL SPILL PREVENTION, CONTROL, AND COUNTERMEASURES COMPLIANCE MONITORING

With the enactment of the FWPCA Amendments of 1972, the EPA sponsored research and demonstration projects to assess the feasibility of using remote sensing techniques for monitoring oil refineries and industrial activities.[8,9,10] These efforts concentrated primarily on oil facilities, but they clearly demonstrated the potential of applying the techniques to chemical facilities and spill conditions.

Implementation of the SPCC regulations in 1974 presented the 10 EPA regional offices with the task of monitoring thousands of facilities for regulation compliance. Limited manpower resources to cover the task of the regions greatly restricted effective compliance monitoring. Nationwide there are an estimated 30,000 bulk oil storage terminals, tank farms, and bulk plants, 285 oil refineries, and several thousand more facilities storing and consuming oil. In general, it has only been possible to spot-check sites within a region, concentrating on those facilities with high spill potential in close proximity to major waterways and responding to specific spill complaints and reports.

At the request of the EPA's Oil and Special Materials Control Division (OSMCD) in Washington, D.C., the Environmental Monitoring and Support Laboratory (EMSL-LV) in Las Vegas, Nevada, implemented an aerial photographic reconnaissance program to assist the SPCC compliance monitoring efforts of each of the EPA regions.[11] In the first year and a half of operations, EMSL-LV conducted aerial surveys in 9 of the 10 EPA regions. These surveys covered 56 large refineries, 235 bulk oil storage terminals, 100 chemical-related facilities, 29 power utilities, 23 railroad yards, and nearly 150 other industrial sites having some type of petroleum product storage.[12] As a result of these missions, numerous oil spills and potential spill conditions were documented. As an example, aerial photography obtained in the San Francisco Bay area, EPA Region IX, indicated some 90 instances of potential SPCC violations. Followup ground inspections found 31 violations, and appropriate citations were issued.

The typical SPCC reconnaissance report includes a summary of the project operations, a detailed index of all facilities photographed, maps showing the location of each site, large-scale color prints with a transparent overlay with the coded analysis (Figure 1), and a textual summary of the photo analysis of each site. An index to the interpretation code is printed alongside each photograph to facilitate an understanding of the code used on the overlays (Figure 2).

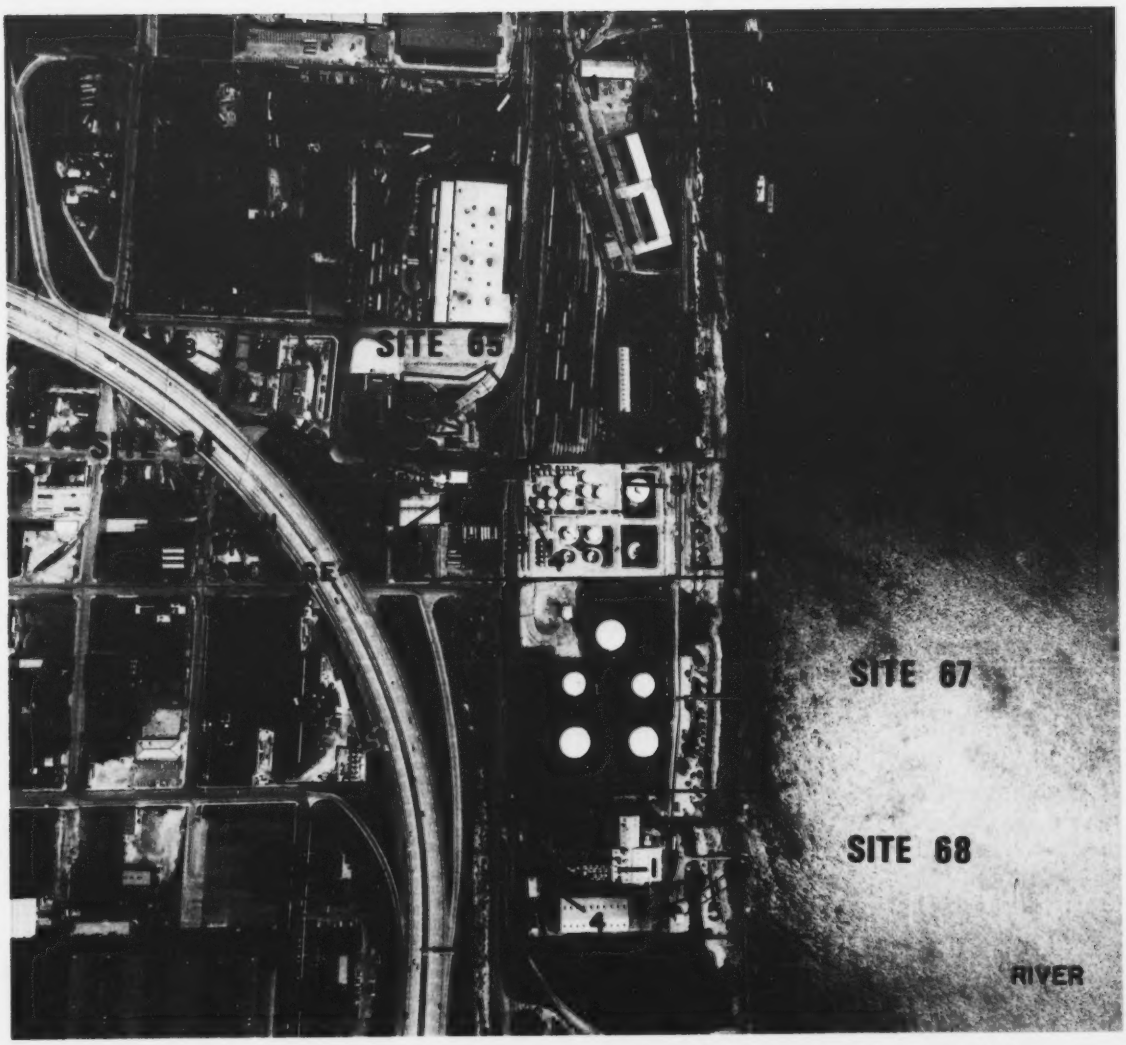

Figure 1. Typical oil SPCC reconnaissance photograph with coded photo analysis.

SPILL CONDITIONS	INTERPRETATION CODE
No secondary containment	1
Breach in secondary containment	2
Inadequate secondary containment	3
Product spillage outside containment	4
Point of entry of old spill into drainage	5
Oil slick and/or sheen on water	6
Leaking or deteriorating tanks	7
POINTS OF INTEREST	
Tank car/truck loading racks	8
Drum storage area	9
Waste water treatment facilities	10
Waste water outfall	11
Vegetation damage	12

Figure 2. Index to the oil SPCC reconnaissance interpretation code.

The data obtained from the imagery provide an excellent source of information on the general operating conditions within a plant and on the drainage pattern leading to the nearest waterway, as well as a general inventory of the tanks and equipment within the plant. In addition, the photographs serve as excellent facility maps for a ground inspection team. Utilizing a reconnaissance report, the regional inspector can plan an inspection itinerary that concentrates on those facilities or locations within a facility that appear to be in noncompliance with the regulations and that bypasses those facilities with no apparent spill conditions. This program of applying remote sensing technology to assist SPCC compliance monitoring efforts has been welcomed by many of the EPA regions and has led to requests for additional aerial reconnaissance flights.

SECTION 5

RECONNAISSANCE PROCEDURES FOR MONITORING HAZARDOUS SUBSTANCES SPILL CONDITIONS

The chemical spill problem is extremely complex in comparison to the problems posed by the prevention, control, and amelioration of oil spills. In addressing chemical spill prevention, consideration must be given to the physical state of the substances (liquid, solid, or gas) and their chemical properties, in particular, flammability, corrosiveness, human toxicity, and reactivity.[13] Hazardous materials must be further categorized as soluble substances, floaters or oily substances, or insoluble or sinking substances before specific spill cleanup measures can be taken.[4]

Notwithstanding these complex conditions, EMSL-LV's experience in performing aerial reconnaissance in support of oil SPCC monitoring has shown conclusively that in most instances product storage and transfer structures, as well as spill containment structures, in a chemical facility are similar to those found in an oil storage and processing facility. When viewed through the lens of an aerial camera, storage and holding tanks, secondary containment structures, pipelines, and product transfer structures are essentially the same for both oil and chemical facilities.

The typical aerial reconnaissance operation over a chemical facility will normally follow the same procedures and techniques used for oil SPCC reconnaissance. Each project is conducted in four stages, including mission planning, data acquisition and processing, image analysis, and report preparation.

MISSION PLANNING

Aerial Cameras

During mission planning, the project leader consults with the EPA regional office requesting the reconnaissance support. The list and identification of facilities or areas to be overflown is compiled. In addition, the sites are put in order of priority based on the region's inspection requirements. Aircraft flight parameters and other data acquisition parameters are specified and combined with flight maps into a flight plan folder.

In past oil SPCC missions, photography has been acquired with RC-8, RC-10, Zeiss, or equivalent cameras. These are standard aerial mapping cameras, which normally have a 15.24-cm (6-inch) focal length, color-corrected lens,

and 22.86-cm (9-inch) film format. A majority of aerial survey firms throughout the country utilize these cameras; thus, this camera type is generally available for contract surveying. Mapping cameras are particularly desirable because geometric distortion is minimal; thus, each photographic print can serve as a photo-base map, which is extremely valuable where current maps are not available or are of inadequate scale. In addition, these camera lenses are suitable for color aerial film, and the resolving power of the optics is sufficient to provide clear, sharp images for analysis.

Aerial Films

Color aerial film is necessary for SPCC reconnaissance missions. The Earth Satellite Corporation study conducted for EPA in 1972 revealed that standard color film was useful for monitoring spill prevention features.[8] Color aerial film is used instead of black and white film since many pertinent target signatures cannot be differentiated on black and white film. In particular, water, oil, and many other substances appear to be the same tone on black and white film. Figure 3 demonstrates the obvious advantage of color film over black and white film for differentiating water from product spillage and dead or damaged vegetation from live vegetation.

The initial SPCC projects in 1976 used Kodak 2445 color negative film with a "clear" filter. This is a high-speed mapping and reconnaissance film that is generally available throughout the aerial surveying community. However, considerable resolution is lost in the process of producing the duplicate film transparency that is required before the film can be interpreted. In addition, the duplication cost is relatively expensive as a result of the high cost of the duplication film (Kodak 4109).

Soon after the initial SPCC projects, a switch was made to color-reversal film, Kodak 2448 and SO-397, both of which are flown with "clear" filters for haze reduction. Both films are slower than the 2445 negative film but match its resolution. These two color-reversal films are duplicated with minimum loss of resolution and at a significantly lower cost when compared to duplicating from 2445 negative film. Both films produce acceptable imagery for analyzing chemical spill conditions. SO-397 is somewhat faster, requiring less illumination and providing better detail in shadow areas. However, 2448 film is generally stocked and more readily available throughout the country, and acquisition of photography through contractors is accomplished more rapidly with this film type.

Flight Parameters

Photography over a chemical facility may be collected at a variety of altitudes depending on the size of the facility being photographed. The primary guideline is to acquire the desired photo coverage in a single pass of the airplane. Experience has shown that the maximum acceptable altitude for the acquisition of color photography for SPCC reconnaissance projects is 4,200 feet (1,280 m) above ground level, which produces a photo scale of 1:8400. Smaller scale photography, acquired at higher altitudes, will often be incapable of resolving the spatial parameters of many engineering deficiencies under observation. Overflights of very large facilities, covering a lateral

Figure 3. Comparison of target signature differentiation capabilities between color and black and white photography over a portion of a chemical production facility.

area in excess of 6,300 feet (1,920 m), will require more than one pass of the airplane if the entire facility is to be inspected. Normally, all flight-line altitudes are planned at 4,200 feet (1,280 m) above ground level so that photo scales are constant.

Clear weather--i.e., no clouds or cloud shadows over the facility being photographed--is a necessary data acquisition parameter. In addition, a sun angle of 30° or higher is required. Sun angles of less than 30° create excessive shadows, especially within processing areas where there may be numerous high structures; as a result, features of prime interest may be obscured. Low sun angles during the winter months, coupled with snow cover on the ground, generally restrict the conduct of aerial reconnaissance in the northern latitudes of the United States to the late spring, summer, and fall months. Reconnaissance operations over chemical facilities in the southern United States, i.e., latitude 30° or less, are not adversely affected by sun angle restrictions and can generally be scheduled throughout the year, weather permitting.

The final step in mission planning is the assembly of the final flight maps, with designated flight lines drawn on them, and completion of a "flight plan" form which specifies the sensor, film, filter, and flight parameters for each site to be overflown.

DATA ACQUISITION AND PROCESSING

At the completion of mission planning, the flight maps, flight plan, and film are delivered to the aircrew (pilot and aerial photographer). At that time the aircrew is briefed on details of the mission requirements, and any technical questions are resolved. Should it be necessary to contract the data collection, aerial survey firms in the area to be overflown are contacted to solicit bids to fly the photography. The flight maps, plans, and logs are sent to the firm selected to fly the mission. If the firm does not have the required film in stock, EMSL-LV also provides the original film.

Once the mission is completed, the original film and logs are returned to Las Vegas for processing. The original film is developed and carefully screened by the project leader image analyst to evaluate the quality and accuracy of the mission coverage. Once accepted by the image analyst, the film is titled and returned to the photo lab for duplication. A duplicate color film positive is required for detailed analysis, and selected color prints are required for the mission report.

IMAGE ANALYSIS

Photo interpretation is conducted on the duplicate positive film transparencies using a light table and a zoom stereoscope. The stereoscope not only provides the necessary magnification but also allows viewing and studying each facility in three dimensions. With the capacity of viewing height differences, the adequacy and integrity of containment structures and the slope and direction of surface drainage can be properly assessed. Image

analysis includes the evaluation of spectral contrasts (color and tone) within the image as well as spatial patterns such as size, shape, geometry, and height of specific features of interest.

Image analysis is centered around the 12-item interpretation code developed for the oil SPCC reconnaissance projects (Figure 2). Each facility is scrutinized for conditions listed in the code. A transparent overlay to the photograph is annotated with the analysis results using the proper code number. Unique conditions not covered by the code may be annotated on the photo overlay using abbreviated phrases, or the condition may be keyed to the text where it is fully described.

RECONNAISSANCE REPORT

In the final phase of a reconnaissance project, the results of the photo analysis are incorporated into an 11-inch by 15-inch (28-cm by 38-cm) spiral-bound report, described in Section 4. Each site is identified by facility name, if available. All sites are located on large-scale maps, and these maps are referenced with the photograph of each site located on the map. A photo analysis summary is written for each site, highlighting any spill or potential spill problems seen in the photography. The coded overlays and photographs are reproduced, collated with the text and maps, and then bound for delivery to the region.

SECTION 6

HAZARDOUS SUBSTANCES SPILL CONDITIONS

It is fully recognized that any spill control and prevention measures that have been undertaken by a company for a facility or group of facilities have been accomplished without benefit of "Federal guidelines or regulations, nor the assistance of industrial codes or regulations developed over the years by a trade association such as the American Petroleum Institute."[14]

Thus, many of these measures have been "custom-designed" for a particular facility or for the substances being handled. One such facility is the Niagara Plant of the Hooker Chemicals and Plastics Corporation, in Niagara Falls, New York.[15] In the absence of regulatory guidelines, Hooker adopted "best engineering practices to eliminate possible pollution incidents as a result of spills." Many of the containment measures undertaken by Hooker at this plant are identical to those found in a typical oil handling facility and could be expected in any oil SPCC plan. Thus, "best engineering practices" guidelines can result in a spill prevention plan that is remarkably similar to a typical oil SPCC plan implemented under Federal regulatory guidelines.

The primary facilities within a chemical storage and production complex that are amenable to aerial surveillance include: (1) product storage facilities, such as storage and holding tanks, and dry product stockpiles; (2) product transfer facilities, such as marine and river terminals, tank car and truck racks, in-plant pipelines, and dry product conveyers; and (3) plant surface drainage and waste treatment facilities. It is recognized that materials produced, stored, processed, and transported within a chemical complex are not all "designated hazardous substances." However, the contents of tanks, pipes, and so forth cannot be determined directly from photography; thus, all anomalies detectable from the film are considered a potential spill condition.

Specific features that can be readily detected in color aerial photography are divided or grouped into two broad categories. The first group of features or conditions are those that relate directly to a spill or spill threat. The list of these features includes:

1. The total absence of secondary containment
2. A breach in secondary containment
3. Inadequate secondary containment

4. Product spillage or stains outside a containment structure

5. Leaking or deterioriating tanks

6. Point of entry of product spill into the natural drainage system

7. Product slick or sheen on water surface or discolored water

8. Damaged vegetation

In the second group are features that, while not directly related to spill conditions, are often the site of numerous spills and are considered potential spill areas. These areas warrant careful scrutiny when the aerial film is interpreted. Within this group are such features as:

1. Tank car and truck loading racks

2. Large drum storage/staging areas

3. Waste water treatment facilities and waste dumps

4. Waste water outfalls

HIGH SPILL-RISK CONDITIONS

Storage tanks and the condition of their associated containment structures are the principal targets for a spill reconnaissance. Most secondary containments are earthen dikes that are readily discernible in the aerial photography. The structural and containment integrity of most of these dikes can be assessed with little difficulty. In a more confined situation such as a processing area, containment may consist of concrete or steel walls. These are more difficult to assess because of their smaller size and the fact that they are often obscured by shadows from nearby tanks or other structures.

Breached dikes are not uncommon. Many dikes are deliberately breached to facilitate entrance of vehicles and equipment for tank repair or construction. However, when evidence of construction or repair activities is absent, a breached dike is considered evidence of a spill threat. Ideally, entrance and exit ramps should be present to permit vehicular access to the diked area.[16]

Adequacy of a containment dike is based on the condition of the dike, i.e., whether it is badly eroded or in poor condition, and a judgment as to the capacity of the dike to hold at least 100 percent of the volume of the largest tank within the dike.

In addition, large amounts of standing water within a containment dike reduce its capacity to contain a product spill, thereby posing a spill threat.

The total absence of a containment structure can be determined easily. Where no containment structure is visible, the image analyst determines if a

spill of any significance from the tank would be confined to the facility property or enter into the natural drainage system.

Many dry (nonliquid or gaseous) products and raw materials found within a chemical production facility are often stored in the open with little more than a temporary wall erected as a containment structure. Spills can occur from overloading the structure, collapse of the structure, or simply leaching and washout during heavy rains. Evidence of spills of this nature is often discernible with aerial photography.

Spill stains outside secondary containments are not always evidence of a threat to the environment. Spill stains are common throughout chemical production facilities. Most are small and confined to areas with adequate protection to the drainage system. However, where stains are numerous and heavy, close scrutiny of the film is warranted to determine the source of the spills and whether or not any spillage has entered the natural drainage system.

Leaking or deteriorating tanks are easily detected on the color film; however, no spill threat is posed if the tanks are adequately contained and there is no evidence that leakage is escaping the containment by way of the drain valve or gate.

All drainage features in the vicinity of processing and storage areas warrant close surveillance. Evidence of the product leakage or spillage from the facility may include a sheen, slick, or discoloration on the water surface. Once the point of entry of the discharge is identified, nearby facilities are carefully scrutinized in order to detect the potential sources.

Damaged or dead vegetation is often evidence of a product spill or leakage from nearby facilities. Damaged vegetation can be readily seen in color photography and is a good indicator of a present or past spill condition.

POTENTIAL SPILL AREAS

Numerous product spills and resultant stains are quite common at points of transfer, in particular at tank car and truck loading racks and the onshore portions of river and marine terminals. The loading racks require careful inspection to verify that large spills would not pose a threat to nearby drainage. Both rail and truck racks should have an impervious (concrete) loading unloading area and drainage engineered to direct any product spillage into nearby sumps, catchment basins, or the waste treatment systems.[13]

Spills at river and marine terminals pose the most direct threat to the natural drainage system. The aerial film should be analyzed carefully to determine the presence of spill prevention features. Containment booms (for floatable substances) should be in evidence at river and marine terminals, either deployed during product transfer or located nearby for quick deployment should a spill occur. Boom deployment often requires a motor launch, and one should be located nearby in case of an emergency.[16]

Drum storage areas are commonly the site of many spill stains, yet more often than not these areas have no secondary containment structures. Therefore, once a drum storage area is located in the photography, the surrounding areas are carefully searched for evidence of spillage or leakage reaching the nearby drainage.

Waste water treatment facilities and waste dumps are carefully inspected to ensure that waste material has not leaked, leached, or otherwise spilled into the nearby drainage system. Damaged vegetation in the vicinity of these facilities often indicates the presence of product spillage. All waste water outfalls are also inspected to see if they emanate from the waste treatment facility or possibly an untreated source.

SECTION 7

PHOTOGRAPHIC SURVEY OF HAZARDOUS SUBSTANCES SPILL CONDITIONS

AERIAL PHOTOGRAPHY

In August of 1976, EMSL-LV collected color aerial photography over a wide range of chemical processing, storage, consumption, and handling facilities. In these areas there are approximately 200 major chemical production facilities, plus an untold number of storage, consumption, and handling facilities.

The photography collected for this project was Kodak 2445 color negative film, with a "clear" filter, acquired with a Zeiss RMK mapping camera with a 6-inch (152.4-cm) focal length lens. Vertical exposures were taken at 2,500 feet (762 m) above ground, producing an approximate scale of 1:5000. Oblique exposures were taken over many facilities at 1,500 feet (457 m) above ground level. Oblique photography was acquired primarily to document spill conditions for inclusion in this report. Oblique exposures are more readily read and understood by the untrained or inexperienced viewer than vertical aerial photographs. Only vertical photography is normally acquired for reconnaissance purposes.

In addition to the photography acquired specifically for this project, photography collected over chemical-related facilities during the course of routine oil SPCC reconnaissance overflights also provided a source of photographic examples of spill features and conditions.

The majority of the photographic prints in this section of the report have been enlarged to clearly depict the spill features of concern. Normally, photo analysis is performed at the original scale, using stereomicroscopes to enlarge the scene when necessary to resolve small features.

PHOTOGRAPHIC EXAMPLES OF SPILL CONDITIONS

Typical in-plant facilities covered in this section include: product storage facilities, product transfer facilities, waste treatment facilities, and drainage.

Product Storage Facilities

Storage facilities include tank farms and isolated tanks, holding tanks (day tanks) generally located within processing areas, drum storage/staging facilities, and dry product or raw materials stock piles. When viewing the

photography, the image analyst interpreter must assess the structural integrity of the primary containment features--tanks, or containment walls and covers (roofs) in the case of stockpiles--as well as the adequacy and integrity of secondary containment features and the potential threats to drainage outside the plant boundary.

Figure 4 is an overview of a large chemical manufacturing facility producing plastics, resins, and general compounded products. There are a large number and variety of storage and holding tanks at this plant, most of which appear adequately contained. Nevertheless, potential spill threats are posed by the two largest storage tanks at the plant (A), which have no visible means of secondary containment. A spill of any significance from either tank would have a clear path to the nearby river. There are product spill stains on the pier leading to the river barge terminal (B), the tank car rack (C), and where some substance has either leaked or has been dumped into the water (D). The four large tank barges noted on the lower-left section of the photograph appear to be permanently moored.

An enlarged view of the dockside section of the plant in Figure 4 is shown in Figure 5. This oblique view shows that the barges are being used for storage of heated product (note the venting steam). The orange and brown stains on the barge tops indicate that in the past the tanks have overflown and the contents have clearly reached the river waters. These four tanks lack any means of secondary containment. The spill stain noted at (D) in Figure 4 is clearly seen at (A) in this view. The spill stain at the tank car rack noted at (C) in Figure 4 is confirmed in this photo at (B). The piers shown in this photo are scattered with discarded hoses, drums, pipes, tanks, and other pieces of wornout equipment--evidence of "poor housekeeping."

Examples of both horizontal and vertical product storage tanks without any visible means of secondary containment can be seen in Figure 6. Both groups of tanks pose a spill threat to the nearby stream. A dark-brown spill stain can be seen at the base of the two horizontal tanks. Note also the product spill leaving the three vertical tanks and entering the stream. Other spill stains are also visible in this cellophane and sodium sulfate production facility. Spillage of a white substance covers much of the center section of this photograph. This material has reached the natural drainage at the two points annotated on the photograph.

Uncontained processing/holding tanks (A) are the apparent source of extensive product spillage in the processing area of the industrial chemical production plant photographed in Figure 7. The orange and white colors of the product spillage are easily distinguished from the pools of standing water in the foreground, apparent remnants of heavy runoff from a recent rainstorm. Some of the standing water has been heavily contaminated by the product spillage, as evidenced by the discolored pools at (B). Dead vegetation on the left is an indicator of the toxic effects of the product spillage. The numerous drums scattered throughout the area are also a potential source of spillage and contamination. Only one tank (C) is adequately contained with a concrete wall.

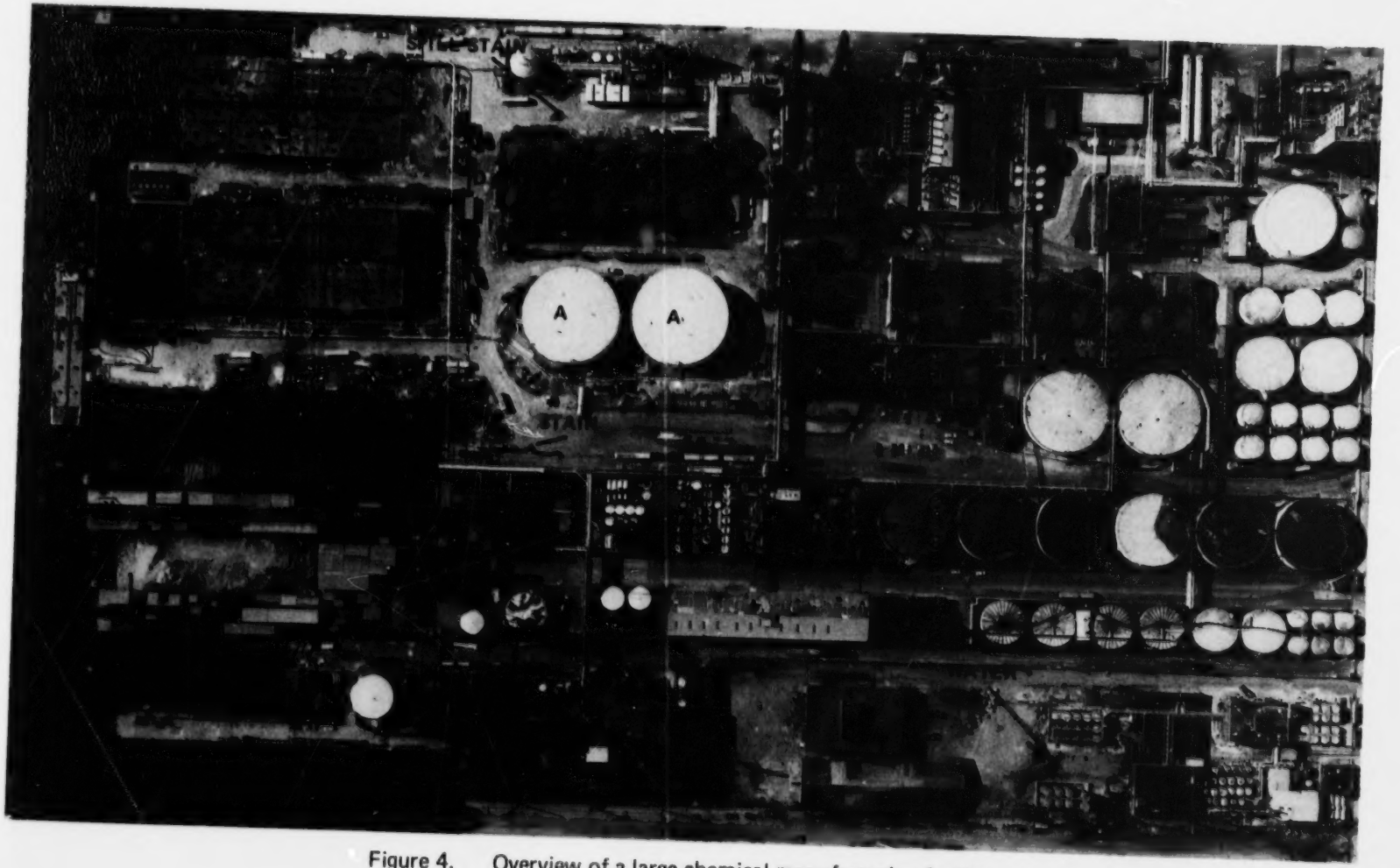

Figure 4. Overview of a large chemical manufacturing facility.

Figure 5. An enlarged or "closeup" view of a small section of the chemical plant in Figure 4.

Figure 6. Uncontained storage tanks at a cellophane and sodium sulfate production facility.

Figure 7. Spill conditions in the processing area of a large industrial chemical production facility.

Quite often the photographs revealed that processing/holding tanks either lacked adequate secondary containment or were totally uncontained. Figure 8 shows an example of uncontained holding tanks that have overflowed, spilling a white substance that has clearly reached the nearby harbor waters. The light sheen identified on the photograph did not originate from this facility but was traced to a large storm drain located out of view of this photograph.

Small chemical packaging facilities commonly lacked secondary containment features for both storage tanks and drums. Figures 9, 10, and 11 display conditions typically found in small packaging operations in the areas surveyed for this study. Spill stains can be seen around the storage tanks and drums, none with secondary containment, at the small facility shown in Figure 9. Standing pools of water (probably remnants of storm runoff) can be easily differentiated from the nearby product spills; nevertheless, this water most likely has been contaminated by the spilled substances. Likewise, the small facility in Figure 10 has no visible means of containing any spills from the

Figure 8. Spillage from processing/holding tanks.

Figure 9. Spill conditions at a small chemical packaging facility lacking secondary containment structures for a number of storage tanks and drums.

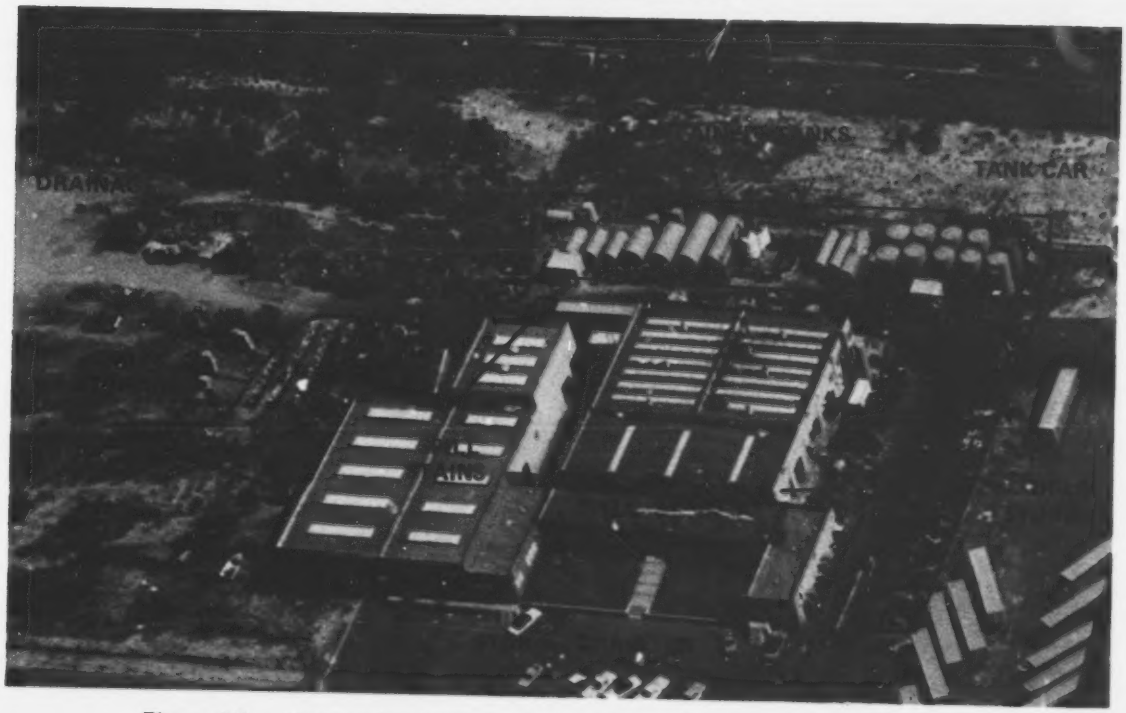

Figure 10. Uncontained tanks and drums at a chemical packaging facility.

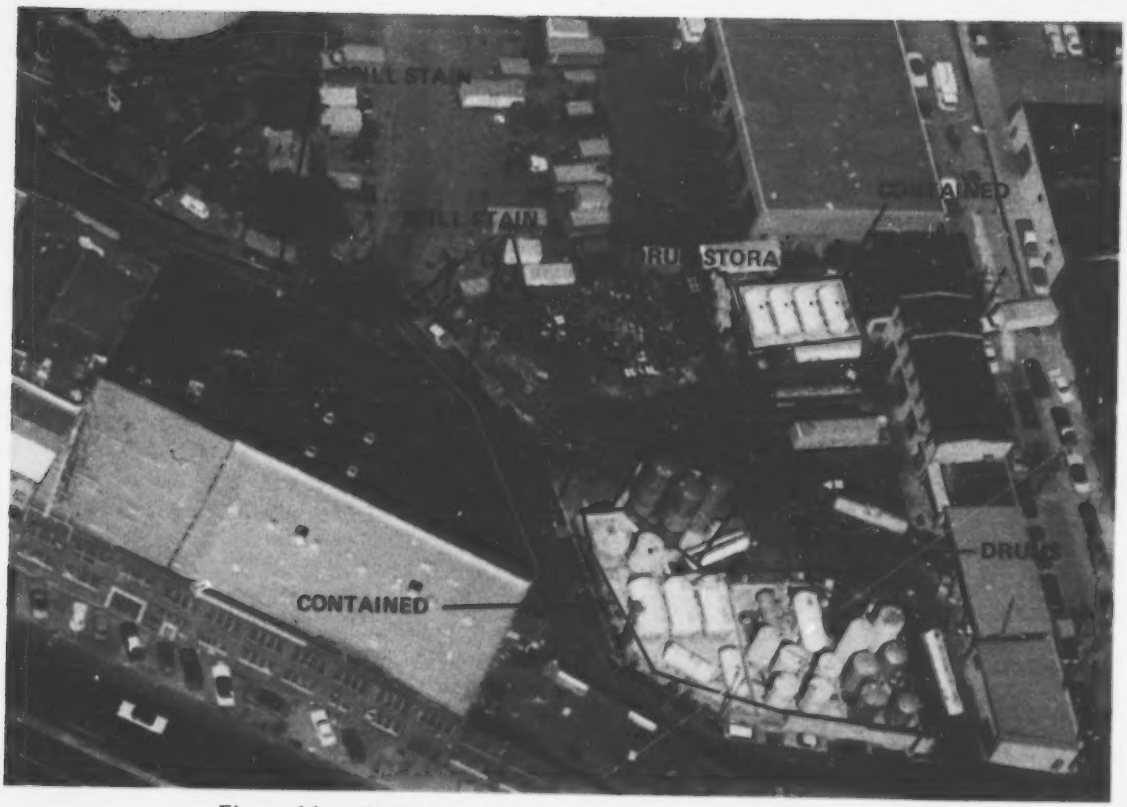

Figure 11. Spill conditions at a chemical packaging facility.

many tanks and drums located there. Any spill in the rear of the building would flow into the drainage ditch that leads to a nearby river. Spills from the drums and loading dock on the right side of the building would likely flow toward the front of the facility and enter the storm sewer system. (Note that the spill from the loading dock (A) can be clearly traced to the storm drain (B).)

Most of the storage tanks at the small chemical packaging plant in Figure 11 have adequate secondary containment. However, none of the hundreds of drums located at this facility has any visible secondary containment. Heavy spill stains are visible in the drum storage area. The three largest storage tanks are without secondary containment, and a large product spill leads from the base of these tanks, past the entrance gate, and several hundred feet into the public street.

Leaking and deteriorating storage tanks can readily be detected in aerial photographs. Product overflow or leaks create a readily identifiable

signature. Figure 12 provides an example of storage tanks stained by overflowing product, probably through vents located at the top of the tanks. Overflowing tanks in themselves are not necessarily a spill threat, except when secondary containment structures are inadequate or absent. However, stains suggest that the tanks have not been closely monitored during filling operations or that the structural integrity of the tanks may be suspect. Stains occurring below the top of a tank indicate the tank may be leaking out of the seams; this may be the result of corrosion and deterioration from within.

Figure 13 is an example of adequately contained storage tanks. The dikes appear to be high enough to contain the contents of most, if not all, of the tanks within them. In addition, should a dike be breached or a drain valve be accidently left open, any spillage would flow into the nearby waste settling pond.

Although absence of drum containment has been cited in several previous figures, examples of the consequences of inadequate drum containment are shown in Figures 14 and 15. Figure 14 is a photograph of a large chemical packaging facility with hundreds of drums stored throughout the facility without any secondary containment. The drums, most of which are painted yellow with others painted blue, white, and black, are the source of product spillage in several instances. The spillage has mixed with standing pools of water at several locations within the plant. A municipal drainage ditch, which leads directly to a nearby harbor, bounds the facility on two sides. Stains at two points near the ditch indicate spillage has entered the ditch. During periods of heavy runoff from rainstorms, the standing pools of contaminated water would also overflow into the ditch. As a result of an absence of secondary containment for the drum storage areas, as well as for a majority of the tanks, and an absence of surface drainage control, this facility poses a significant spill threat to nearby navigable waters.

In the absence of secondary containment structures, drum storage areas can pose a spill threat. An enlarged view of one of several drum storage areas in a large industrial chemical production facility is shown in Figure 15. At two points noted, surface runoff, transporting spillage, leads directly to a drainage canal. In addition, these drums are stored on bare ground that has been saturated from repeated spills and must be considered a potential threat to ground water.

Most of the chemical production facilities photographed for this study had stockpiles of dry product or raw materials. A majority of the dry product storage areas were inadequately contained to prevent the substance from being transported, either by direct overflow, surface runoff, or leaching, to nearby natural drainage systems. Figure 16 is an example of a well-engineered raw material (dry) storage facility. The hopper car rail siding shows no evidence of spillage nor does the unloading facility where the cars are inverted. The material is dumped from the cars onto conveyers beneath the facility and then carried to the storage silos or to the stockpiles noted. The entire stockpile area is recessed several feet below the level of the containment dike. Excess water within the diked area is channeled through drainage ditches to the plant waste treatment facilities.

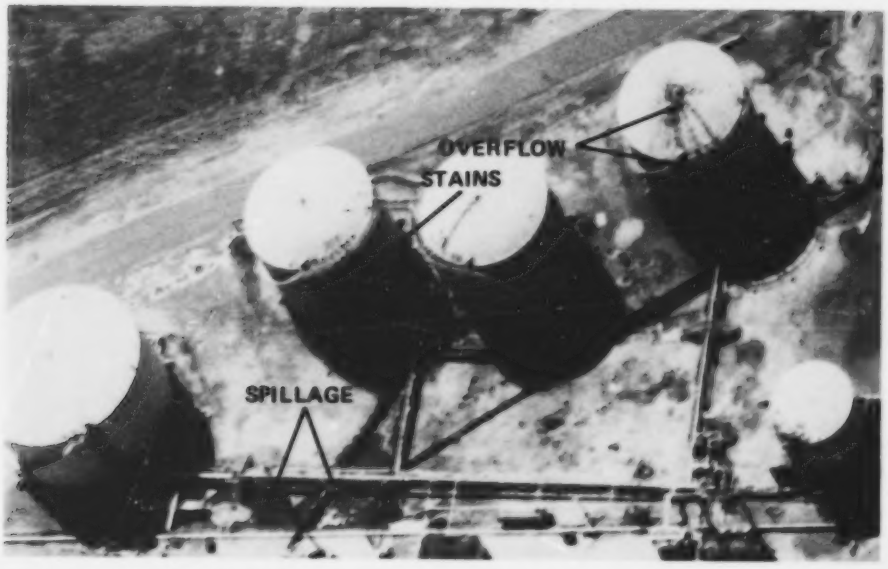

Figure 12. Stained tanks caused by overflow leaks.

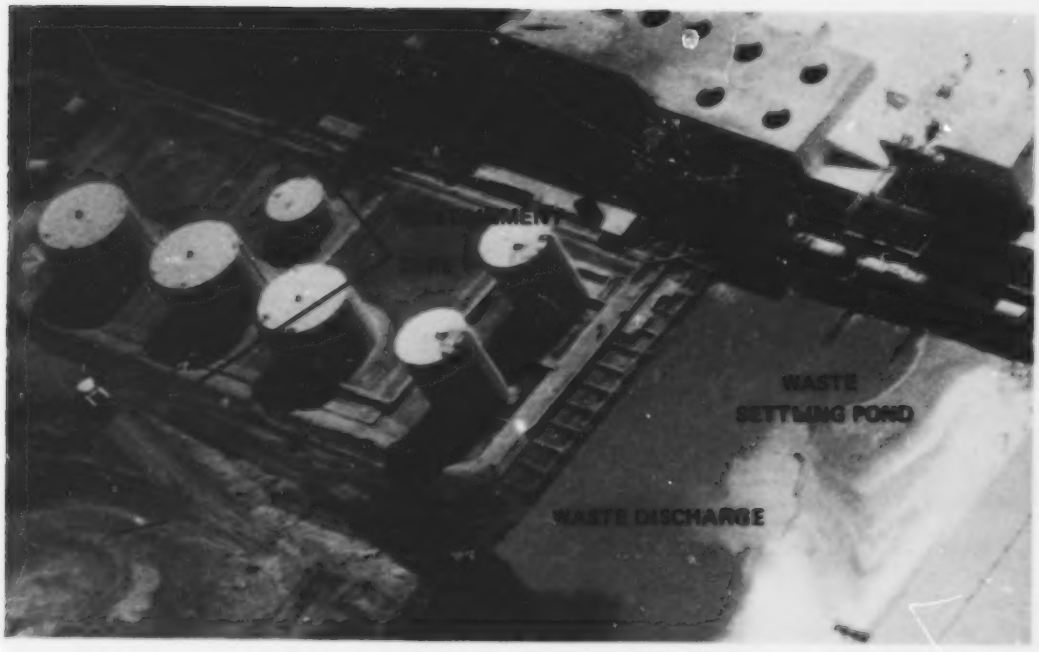

Figure 13. Product storage tanks with adequate secondary containment dikes.

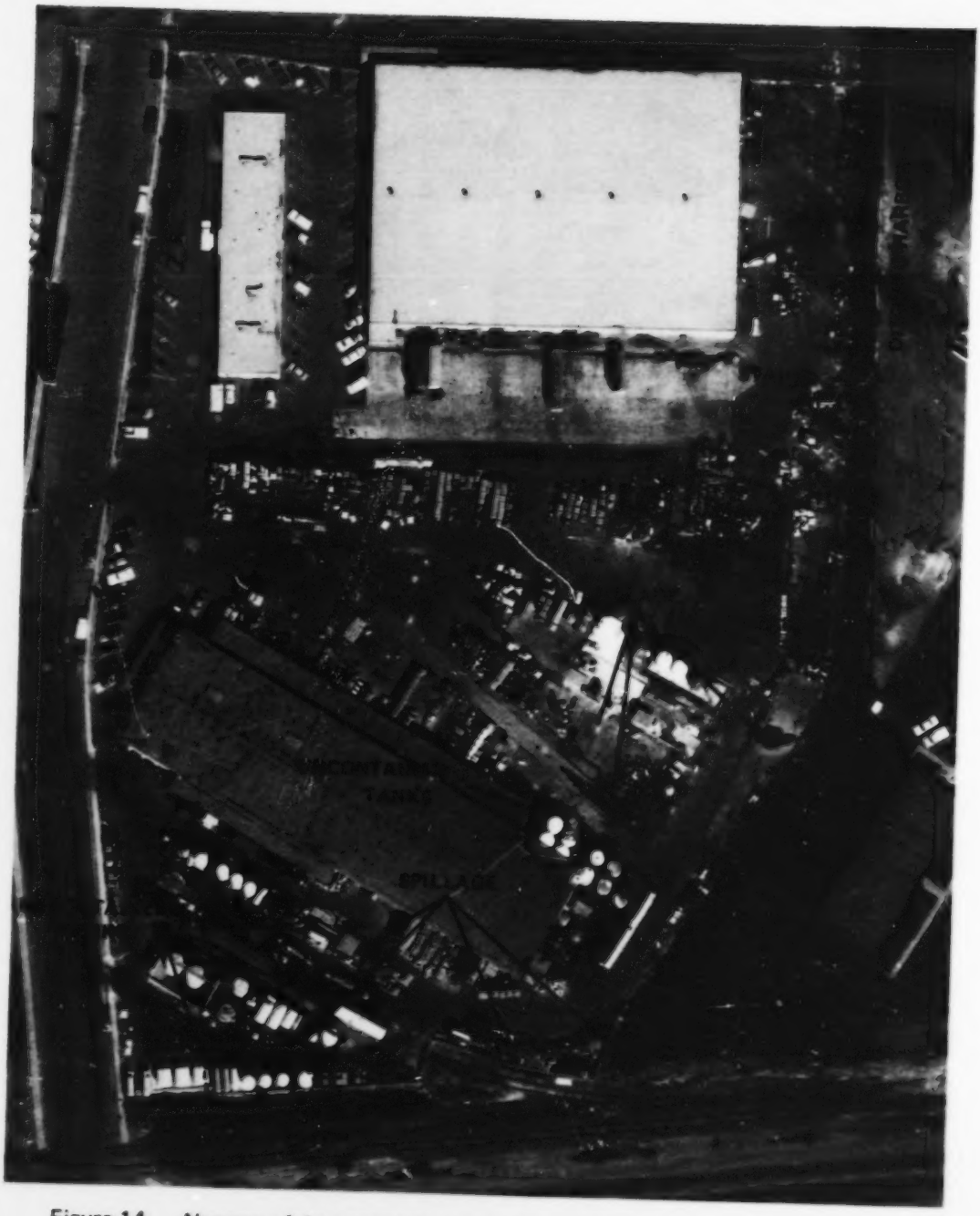

Figure 14. Absence of drum containment and inadequate surface drainage control.

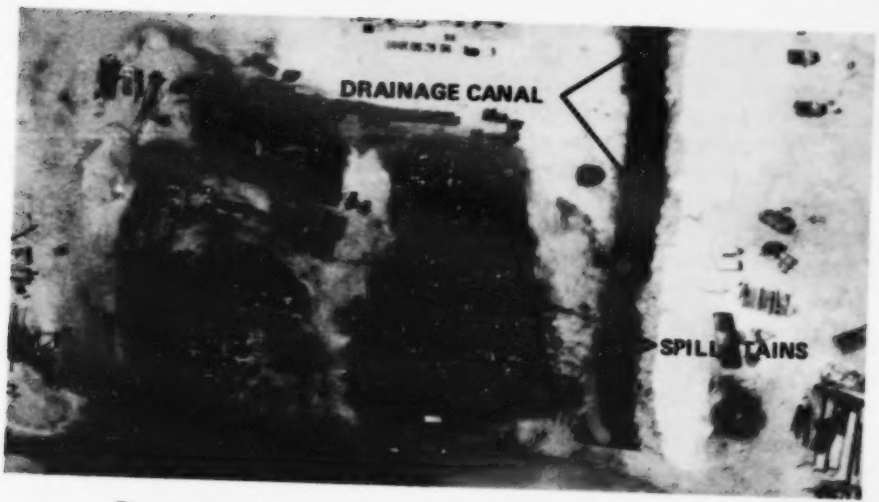

Figure 15. Heavy product spillage in a drum storage yard.

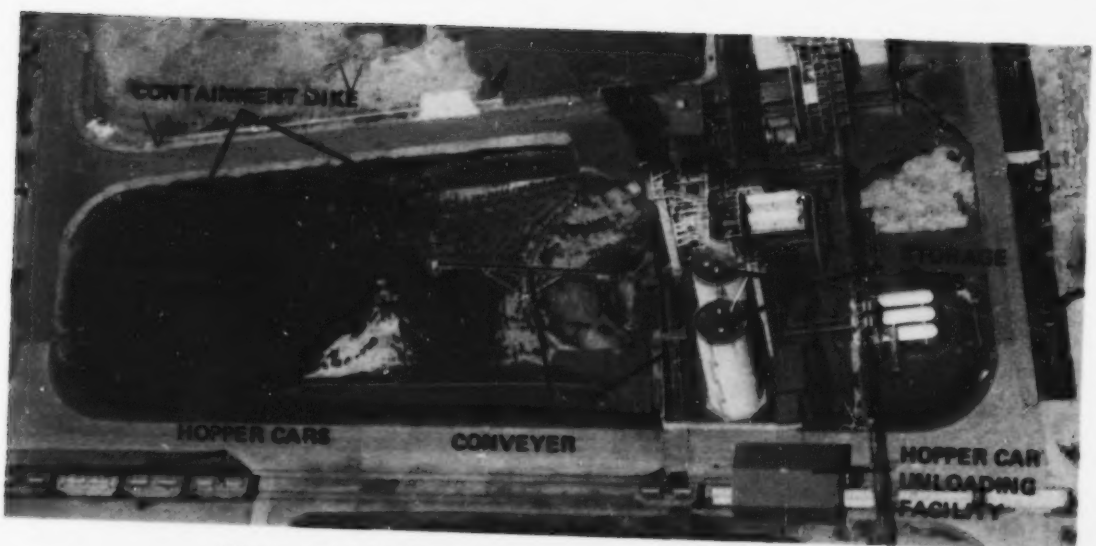

Figure 16. Well-engineered dry material storage facilities.

An enlarged view of a raw material stockpile at a titanium dioxide production facility is shown in Figure 17. This stockpile also appears to be adequately contained. There is no evidence of material spillage or leaching of material beyond the containment wall.

Typical examples of inadequately contained dry product/raw material stockpiles are shown in Figures 18, 19, and 20. The stockpile of yellow substance in Figure 18 has containment on two sides but is uncontained on the other side. At point (A), the material has entered or is entering the river. This material is transported to a hopper on the roof of the plant via a pipelike conveyer. (Note the fugitive dust scattered on the roof around the hopper). During a rainfall, this dust (spillage) will be carried by runoff either into the street or the river. Additional stains are found along the riverbank where material has been spilled or dumped. Among these is a spill stain which, leading from a small concrete drum storage pad (B), has reached the river.

The wetlands bordering the facility in Figure 19 show severe vegetation damage in areas where spillage from the stockpile of black material (possibly coal) has escaped the containment dikes. The areas of heavy spillage are totally void of vegetative growth. There are large pools of water standing within the stockpile area, and seepage and overflow may be causes of the spillage reaching the wetlands. The long incomplete containment wall appears to have been constructed after the nearby spillage occurred. Nevertheless, the vegetation damage remains.

An even more vivid demonstration of the consequences of inadequately contained dry product storage can be seen in Figure 20. The containment wall for this stockpile has been breached in three places causing extensive vegetation damage in the foreground. Even the live vegetation noted does not appear vigorous and healthy but is showing signs of stress. It is very likely that leachate has migrated into the nearby river water.

Product Transfer Facilities

Analysis of the aerial photography revealed considerable product spillage, generally in small amounts, and spill stains in and around product transfer points. This was not unexpected since EMSL-LV's past experience in reconnaissance of oil-related facilities revealed the same situation. Points of product transfer are likely areas for spills to occur. In general, a majority of the facilities viewed had few if any secondary containment or recovery features, such as grated trenches, sumps, and so forth, which could minimize the effects of a major spill.

The photography also revealed that railroad tank car racks are a much more common occurrence than truck racks in the facilities studied. Very few large, centrally located truck racks were detected, whereas in oil production, refining, and storage facilities large truck racks are the norm. Tank trucks were seen in most of the facilities, but points of transfer appeared to be distributed throughout the facilities rather than centrally located.

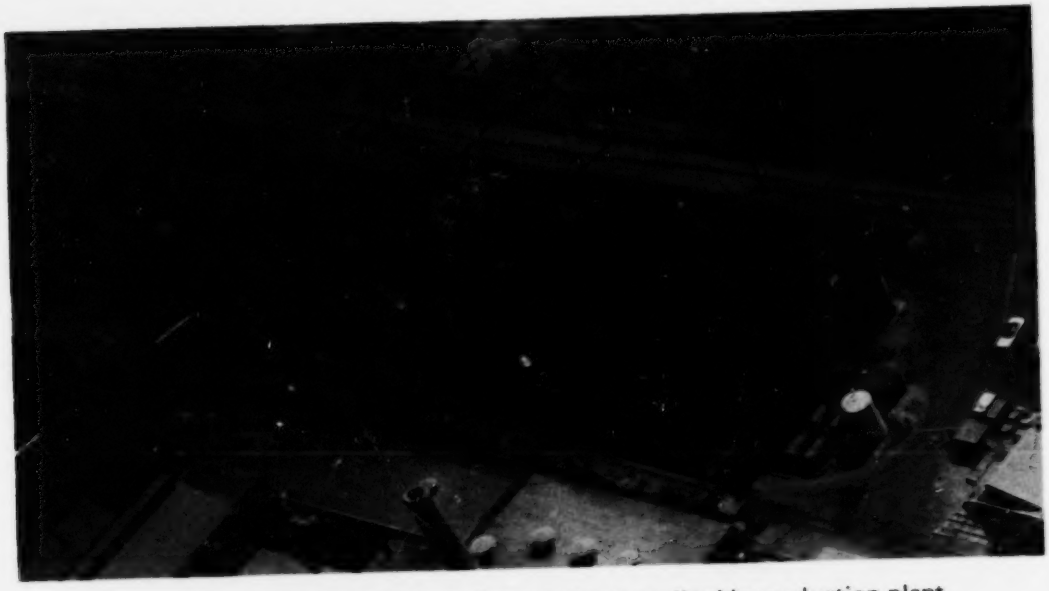

Figure 17. Dry material stockpiles at a titanium dioxide production plant.

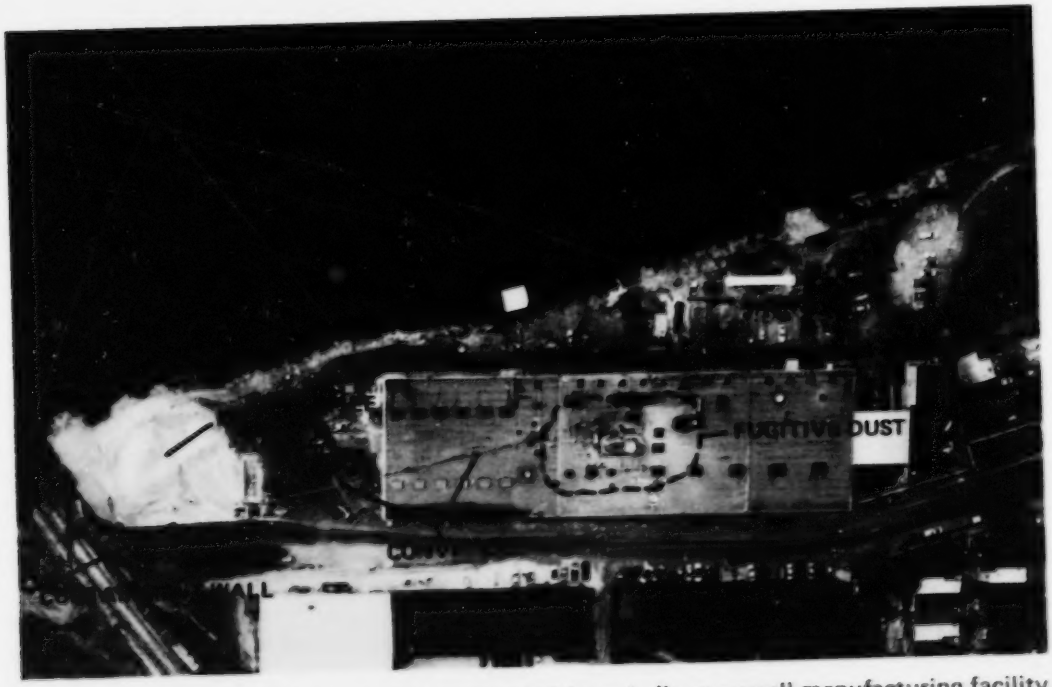

Figure 18. Inadequately contained raw material stockpile at a small manufacturing facility.

Figure 19. Inadequately contained raw material stockpiles at a large industrial chemical manufacturing facility.

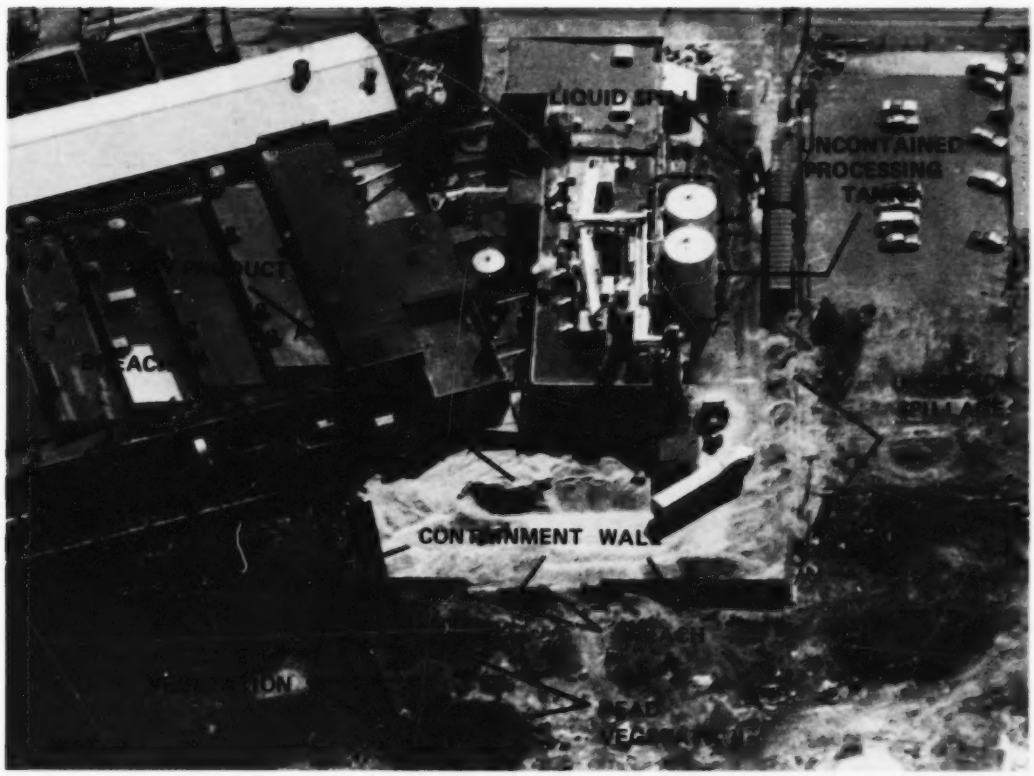

Figure 20. Spill conditions associated with dry product storage.

Figure 21 is an example of a very large tank car facility with well-engineered drainage control. Drainage ditches would carry any major spill from the racks to the plant waste treatment facilities. Figure 22 shows heavy product spillage and spill stains at the tank car racks of a large organic chemical manufacturing plant. Spillage volume is inadequate to flow beyond the racks; however, rainfall runoff would transport some of the spilled product into drainage ditches that bypass the plant's waste treatment facilities and empty into a nearby river.

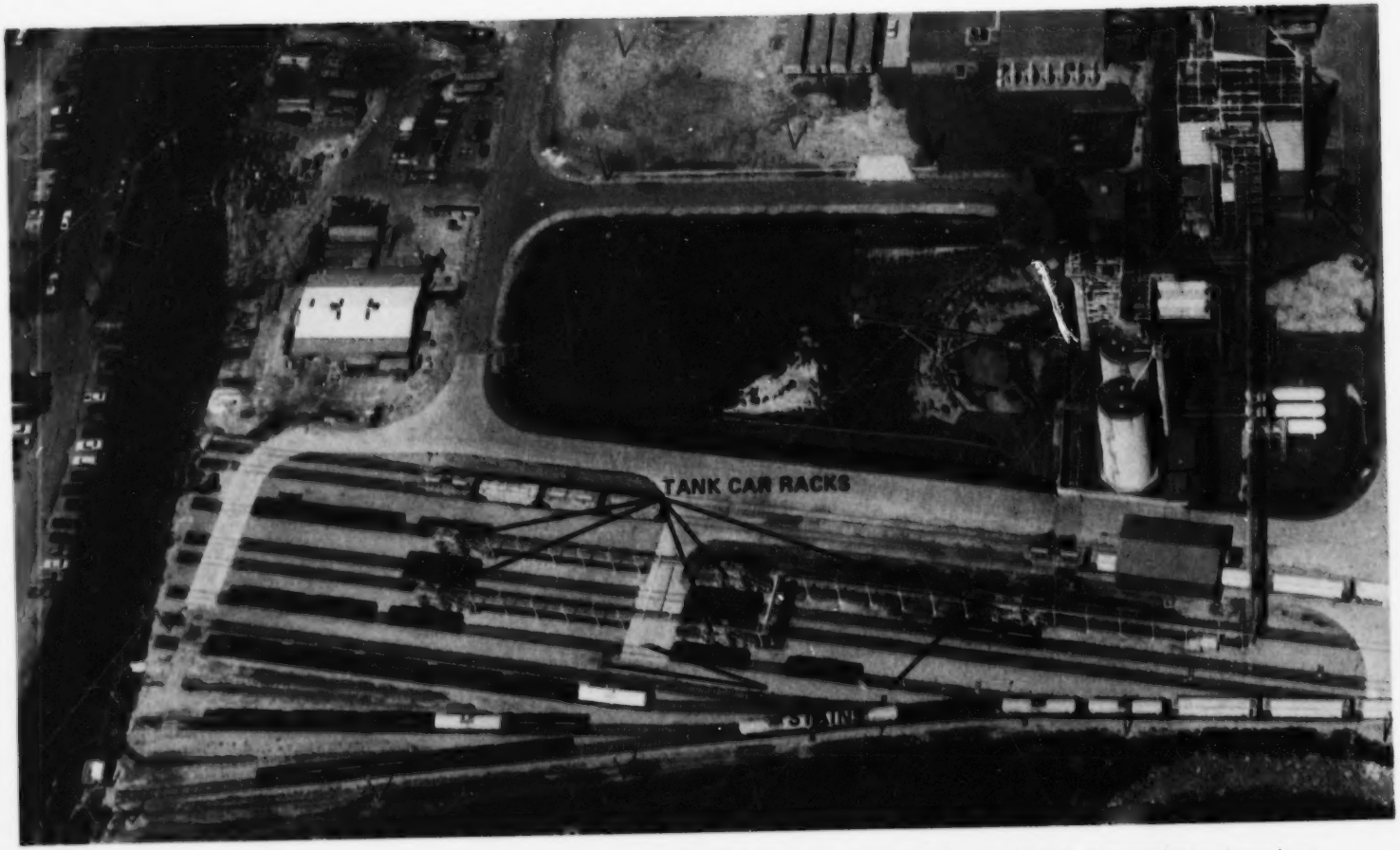

Figure 21. Example of clean, well-engineered tank car racks and rail sidings at a large chemical manufacturing plant.

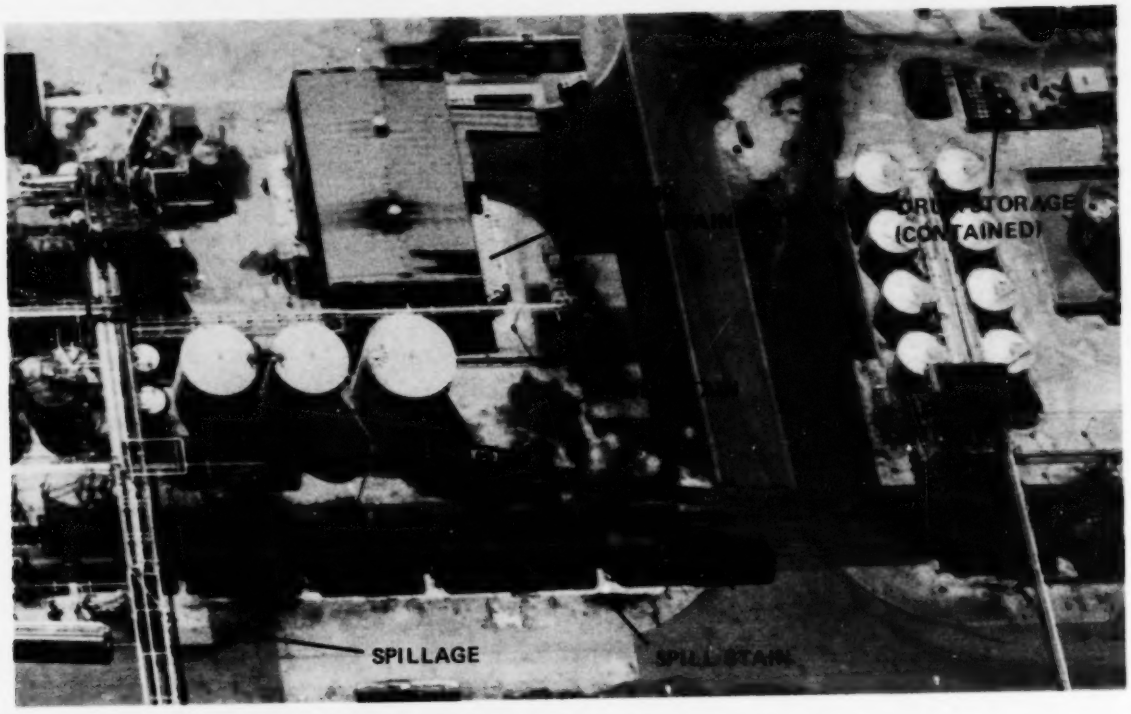

Figure 22. Spill conditions at a chemical tank car rack.

Figure 23 shows several tank car racks and truck racks at a large industrial chemical production complex. Spill stains and product spillage are visible at several points. A major spill at these racks would likely flow into the nearby drainage ditches. Unfortunately, as in the previous photograph, the ditch bypasses a waste settling pond and enters a wetland area bordering the plant.

In Figure 24, product spillage from the tank cars at this small chemical packaging facility is quite heavy. Careful analysis of the photograph shows these stains have reached the river water. Finally, the 10 vertical storage tanks (red) and the drum storage area lack any visible means of secondary containment.

Several marine terminals were photographed for this study. These terminals are indistinguishable from typical oil barge and tanker terminals. Figures 25 thru 27 are examples of typical conditions at marine terminals servicing chemical facilities. Figure 25 is a vertical photograph of the river terminal facilities of a large chemical production complex. Along with barge and tanker docking facilities is the terminal for a large railroad tank car barge (ferry). Figure 26 is a low-altitude oblique view of the same terminal taken one day earlier. The wood plank deck of the barge dock offers no containment should a hose or pipe burst during product transfer operations. The heavy black stains noted on the dock surface are an indication of numerous

Figure 23. Truck and rail tank car racks at a large industrial chemical production facility.

Figure 24. Heavy spill stains at the tank car terminal of a small chemical manufacturing facility.

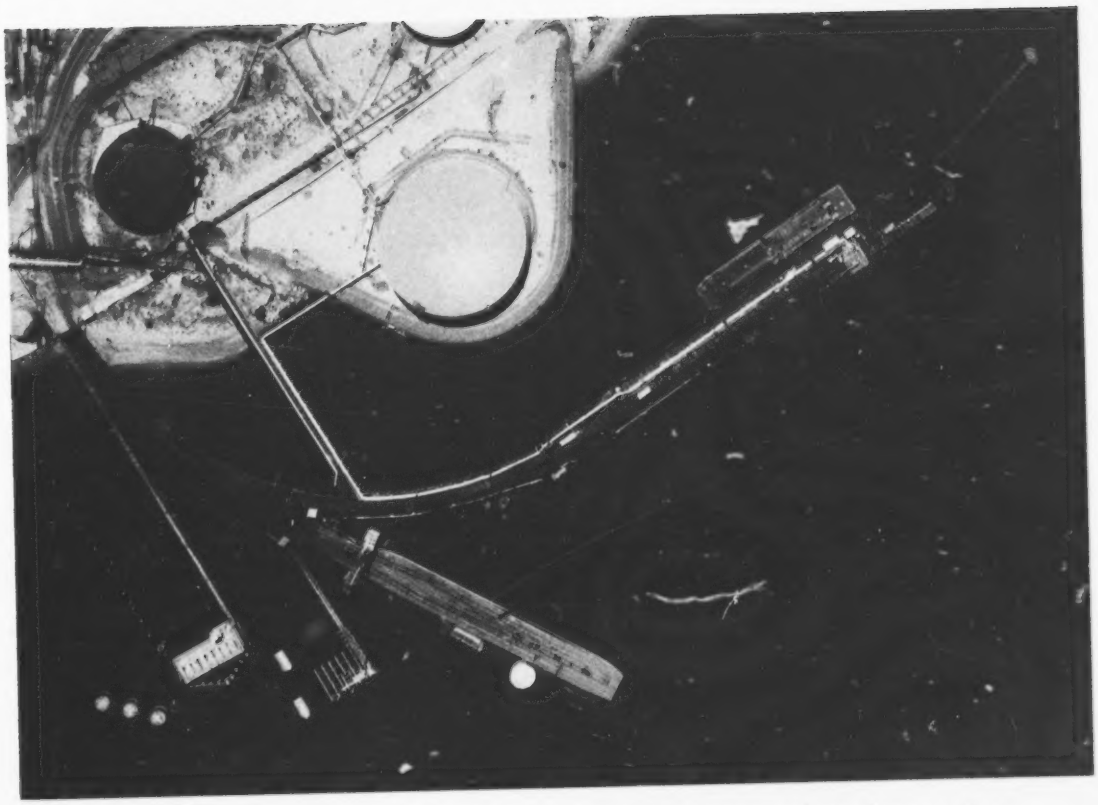

Figure 25. Marine terminal facilities at a large chemical manufacturing complex.

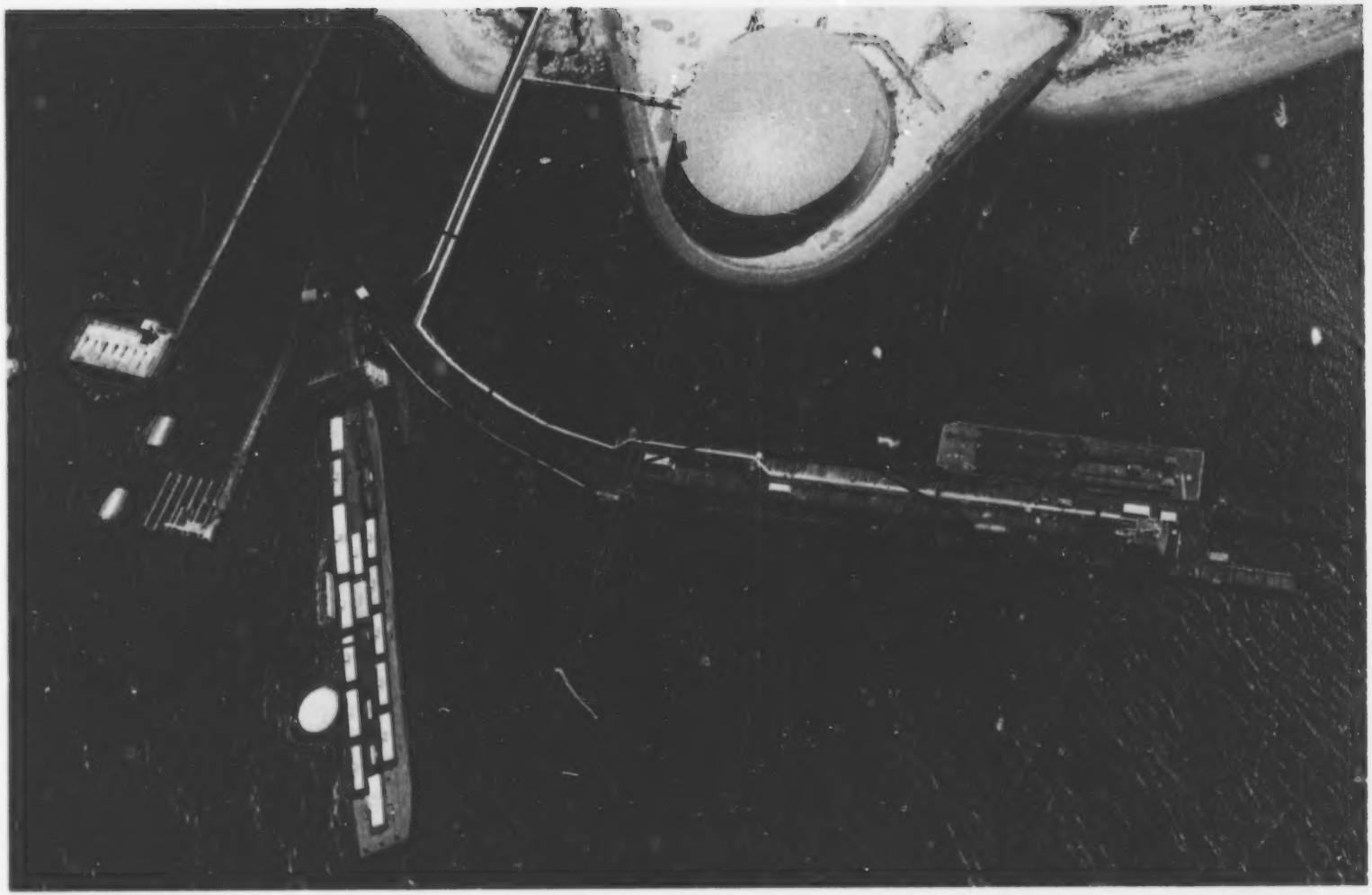

Figure 26. Oblique view of the large marine terminal seen in Figure 25.

Figure 27. Product transfer operations at a barge terminal.

product spills. Notice the subtle oily sheen beneath the stained dock. In addition, the barge is only moored to the dock with bow and stern lines. Additional crossed spring lines would reduce the chances of hose or pipe rupture resulting from surge action caused by the passage of large vessels.

Figure 27 is an example of a smaller barge terminal facility. Any spill occurring during product transfer operations would enter the river unhindered. Booms have not been deployed around these barges as a precaution should a spill occur, and none were stored close at hand for emergency response to a spill. This was the case at all marine terminals photographed for this study.

An example of marine terminal facilities for offloading dry products/raw materials at chemical processing plants is shown in Figure 28. At both of the plants, heavy spillage of the white substance offloaded at the terminals has coated much of the area. Rainfall has washed and will continue to wash much

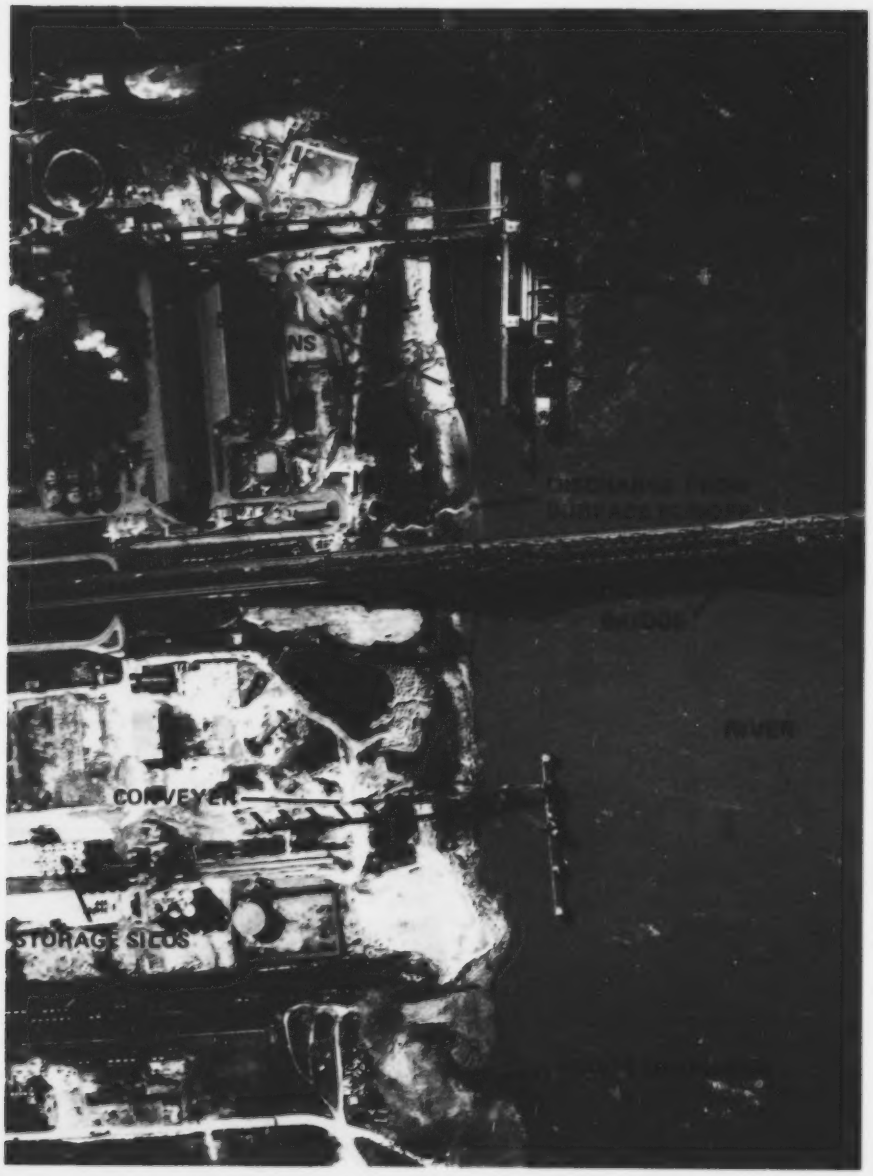

Figure 28. River terminal facilities for off-loading and storing dry product (raw materials) at two large chemical manufacturing plants.

of this spillage into the river. Note in particular the heavy spillage at the ship terminal and the river bank of the facility at the top of Figure 28.

Waste Treatment Facilities and Surface Drainage

Detailed interpretation of the aerial photography acquired over the chemical production and storage facilities in the study area revealed that waste treatment and surface drainage control varied widely from facility to facility. The adequacy of waste treatment cannot be fully assessed from aerial photography; nevertheless, certain deficiencies are readily apparent. The total absence of waste treatment facilities, the presence of discolored or turbid waste discharge plumes into adjacent natural drainage, and the presence of damaged vegetation near points of waste discharge are often indicators of potential deficiencies in waste treatment. Surface drainage within a facility boundary should be interlinked with the waste treatment system so that accidental spills and contaminated surface runoff can be blocked or treated prior to discharge beyond the facility boundary.

Figure 29 is an example of visible waste treatment facilities at a titanium dioxide production plant. All waste substances are channeled to the settling pond to allow suspended materials to settle prior to discharge into the river. Notwithstanding this treatment, waste substances are being discharged into the river. (Note the color of the discharged water and the clearly defined plume created by the discharge.)

An example of inadequate waste treatment can be seen in Figure 30. Four waste water pipes are discharging effluent into a drainage ditch that empties into the nearby river. Only the discharge at (A) has been treated; the others bypass the settling pond. Drainage analysis also shows seepage from a solid waste landfill that terminates in the river beyond the boundary of the photograph. Also, spillage within the containment dike of the three large tanks flows to a sump, through an open gate, and finally into the river. The ditch leading from the sump is deeply eroded, suggesting a continuous and prolonged flow has taken place. Surface runoff from heavy rainfall may be the principal cause of the deep erosion (gullies); nevertheless, the runoff is carrying the spilled product. Near the sump, an overhead pipeline, which connects the river terminal with the main processing area, is leaking into the drainage ditch. Note the brown stains on the pipes at (B).

Surface drainage at the organic chemical production facility shown in Figure 31 has been engineered to bypass the large waste settling lagoons, at least in the section of the facility photographed. As a result, surface spills and rainfall runoff flow directly to the nearby creek. Spillage at (A) flows to the sump (B) formed by a natural depression and the elevated roadway. However, the sump overflows into a culvert under the road and ultimately to the creek.

Figure 32 shows part of the extensive waste treatment facilities of a large chemical manufacturing plant. Additional treatment facilities are located beyond the edge of this photograph. This plant is bordered by a tidal marshland in the foreground, and the photography reveals an extensive area of dead and dying vegetation. The most likely cause is effluent from a drainage

Figure 29. Waste water treatment facility at a titanium dioxide production facility.

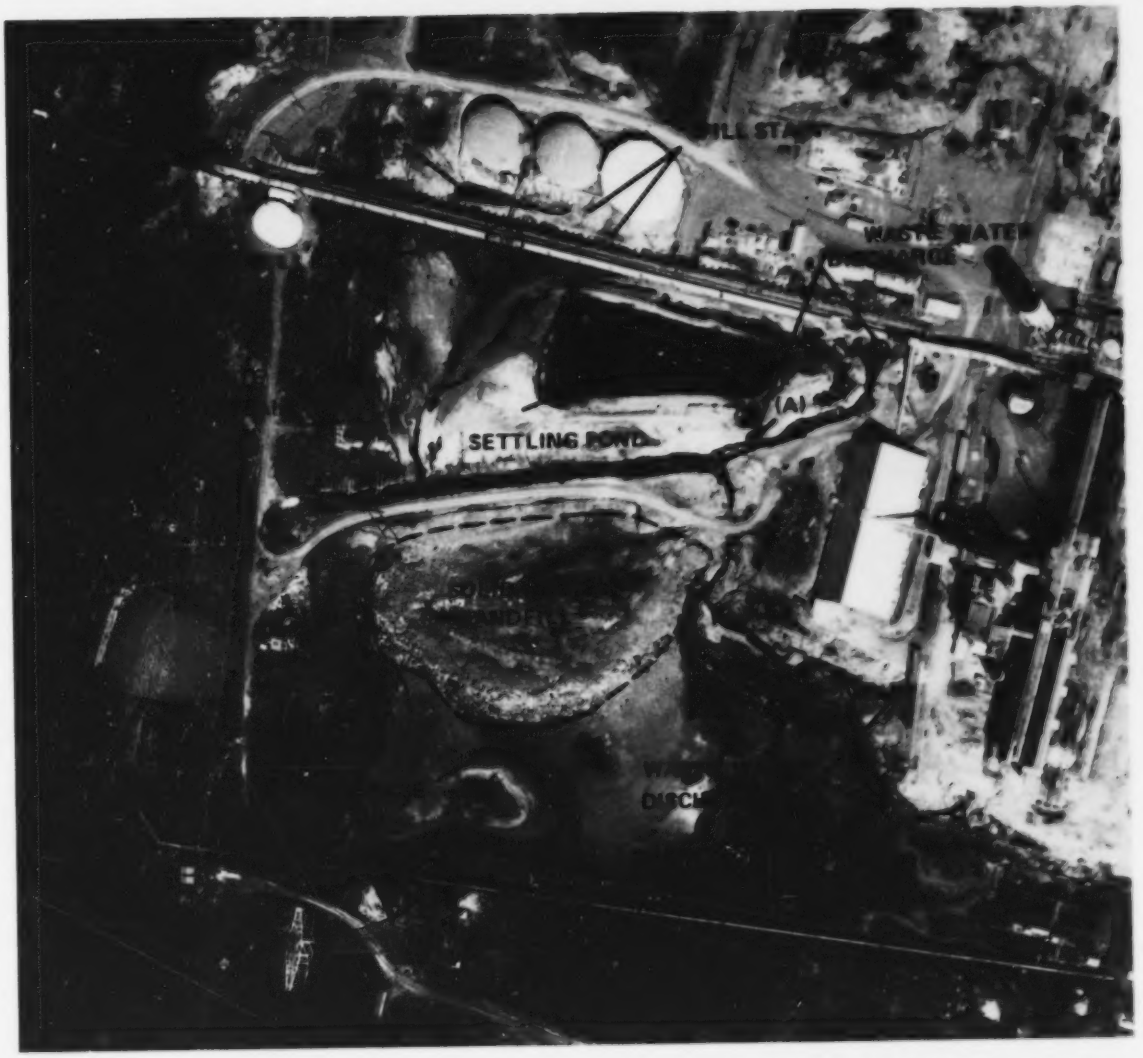

Figure 30. Waste water discharge at a small part of a large industrial chemical production facility.

Figure 31. Surface drainage at an organic chemical production facility.

Figure 32. Damaged vegetation from surface runoff at a large chemical plant.

ditch leading from the plant. Figure 33 provides a closer view of the area drained by the ditch. Product spill stains lead to the ditch network from a large tank car rack (A), uncontained storage tanks at (B) and (C), an uncontained drum storage area (D), and possibly a cooling facility (E).

The plant in Figure 34 also has extensive waste treatment facilities, but much of the surface runoff is directed through ditches that bypass these treatment facilities. These ditches drain a section of the plant that has numerous spill stains and uncontained tanks and drums. Effluent in the ditches passes through a separator, which presumably should draw off oil and other floatable substances in the ditch. However, the turbid plume located at the discharge point suggests that the separator is apparently ineffective for soluble and suspended materials. Note also the damaged vegetation resulting from spillage or dumping near the waste treatment facilities.

Liquid waste, spillage, and surface runoff in the large chemical production facility in Figure 35 are collected by a network of canals and ditches and emptied into a wetland area bordering the plant. This effluent ultimately reaches a nearby river. An enlarged view of the center portion of this plant (Figure 36) clearly shows that the canal bypasses a waste settling pond. Note also that a boom has been deployed at one of the canal intersections and has been effective in skimming off a considerable amount of floating material.

Figure 37 is an enlarged photograph of an old chemical manufacturing plant producing general and compounded products. Except for the deployment of two surface containment booms at waste water discharge points, there are no visible waste treatment facilities. The smaller boom has accumulated a small amount of floating substance, which appears to be a white froth or foam, but has not prevented the passing of the suspended materials in the effluent. In contrast, note how well the second and larger boom has blocked the movement of the turbid discharge. The turbid plume from this waste discharge can be traced several hundred feet down river from this point.

The acrylic resins production facility shown in Figure 38 has no visible waste treatment facilities. The waste water discharged from this plant creates a large, visible plume that extends well into the river. A careful analysis of this plume also revealed the presence of a very thin, oily sheen.

Drainage control at the small chemical packaging plant in Figure 39 is inadequate to prevent any significant spill from reaching the nearby bay waters. Spillage from the truck rack or loading dock would likely follow the path defined by the flowing water, across the parking lot, into the storm drain, and then to the bay.

Seepage from the waste dump at the fertilizer production facility in Figure 40 has created a large oily sheen that extends as a plume several hundred feet into the harbor waters. Standing spillage on the surface of this dump/landfill site and leaching from the dump may both be contributing sources of the plume.

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Figure 33. Oblique enlargement of the facility shown in Figure 32.

Figure 34. Waste treatment and drainage facilities at a large chemical processing plant.

Figure 35. A network of canals and ditches draining a large chemical production facility.

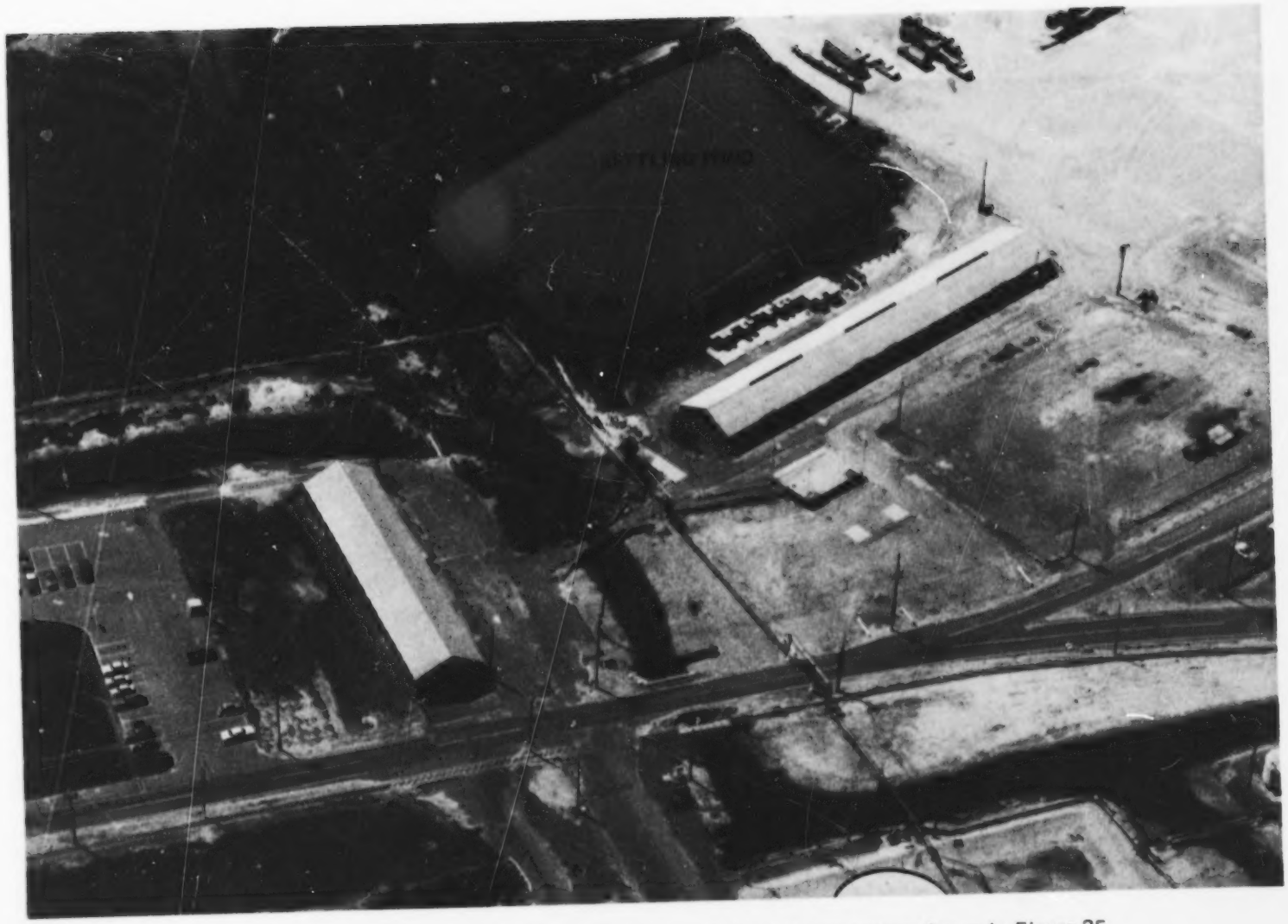

Figure 36. An enlarged, oblique view of a section of the drainage system shown in Figure 35.

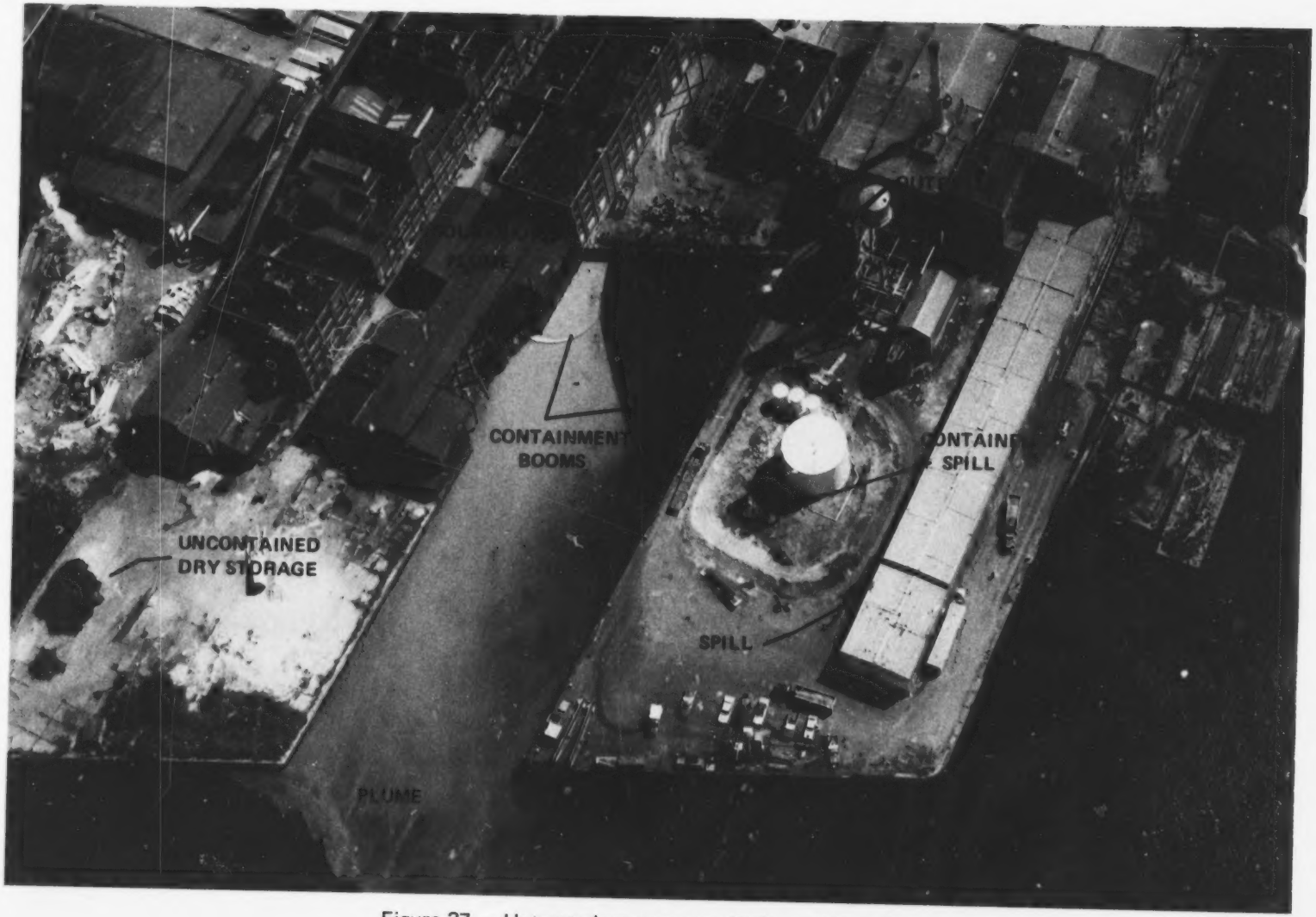

Figure 37. Untreated waste water discharged into river.

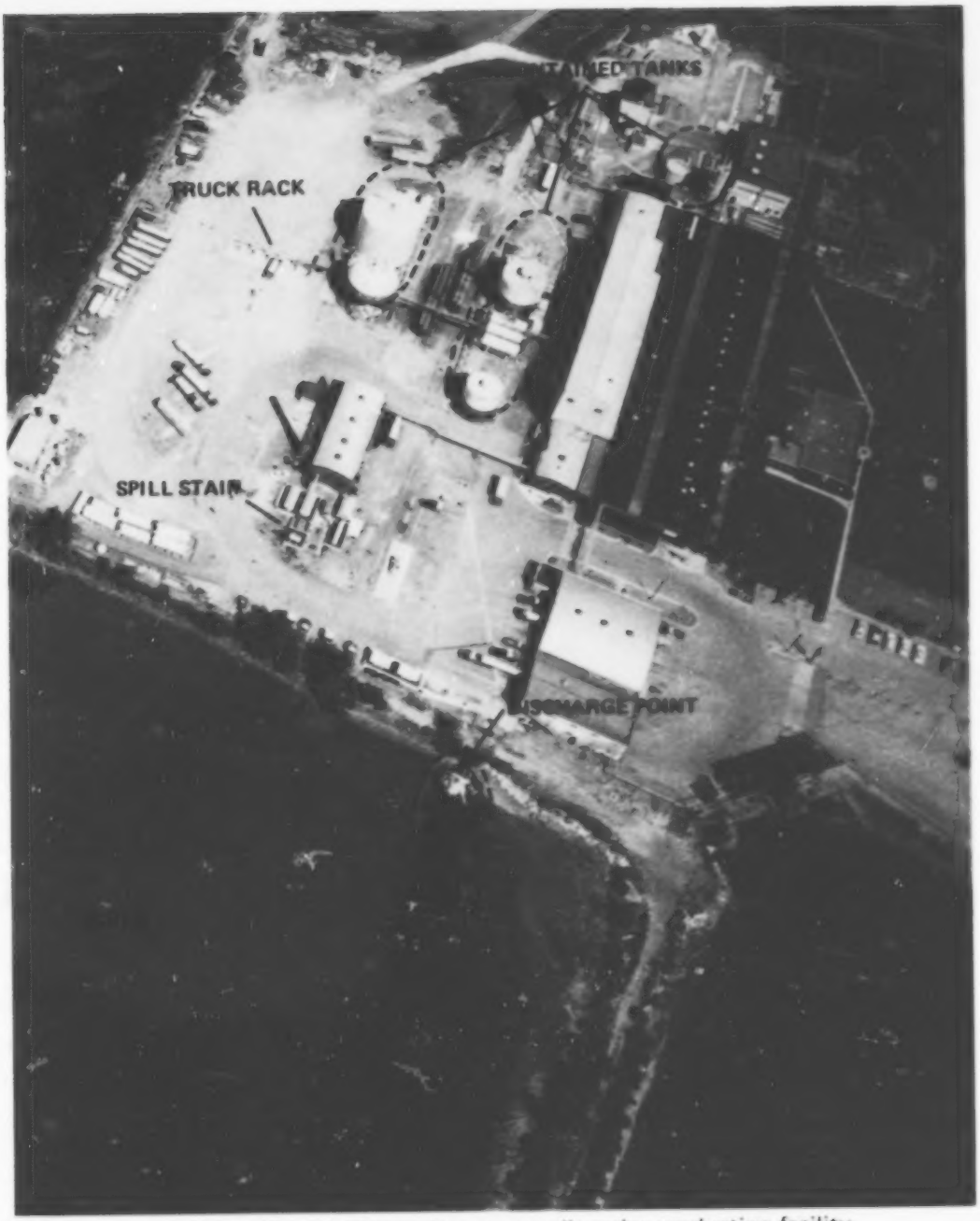

Figure 38. Waste discharge from an acrylic resins production facility.

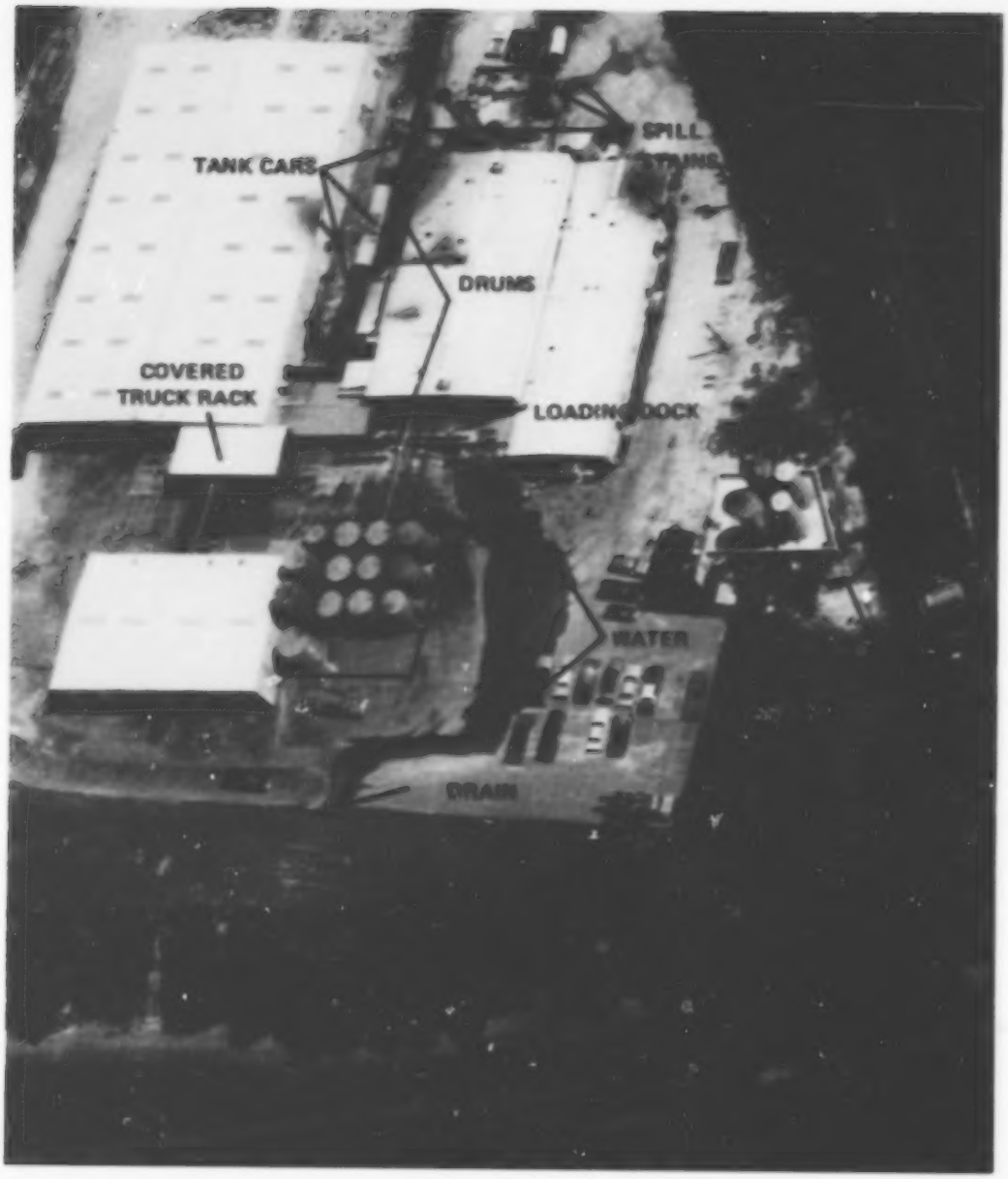

Figure 39. Inadequate drainage control at a chemical packaging facility.

Figure 40. The waste dump at this facility is the source of the oil sheen extending over the harbor waters.

Surface drainage at the large plant in Figure 41 has been engineered to gather surface runoff and transport it directly to a nearby river. Product spillage from several sources can be seen, some of which has entered the drainage ditches. Analysis of the film over this plant showed no visible waste treatment facilities. Rainfall runoff would most likely flush much of the product spillage in this plant into the ditch system.

The tank farm and associated tank car racks at a large chemical manufacturing facility located on very flat, poorly drained terrain is shown in Figure 42. Any major spill would follow the drainage ditch system annotated on the photograph. There are several locations within the facility boundary where the path of spillage could be readily blocked or dammed if equipment and materials were on hand. Upon exiting the facility boundary, the ditch enters the natural drainage system. The large storage tank in the right foreground has a high containment dike that would hold the capacity of the tank. There is standing water in the dike that appears to be draining into the natural drainage through the drain at (A) and into the facility ditch network at (B). A potential spill situation is posed at this facility by the open, untended drains and the absence of materials and equipment to contain or prevent spillage from entering the natural drainage system.

Figure 41. Engineered drainage gathering surface runoff and product spillage for eventual discharge into a nearby river.

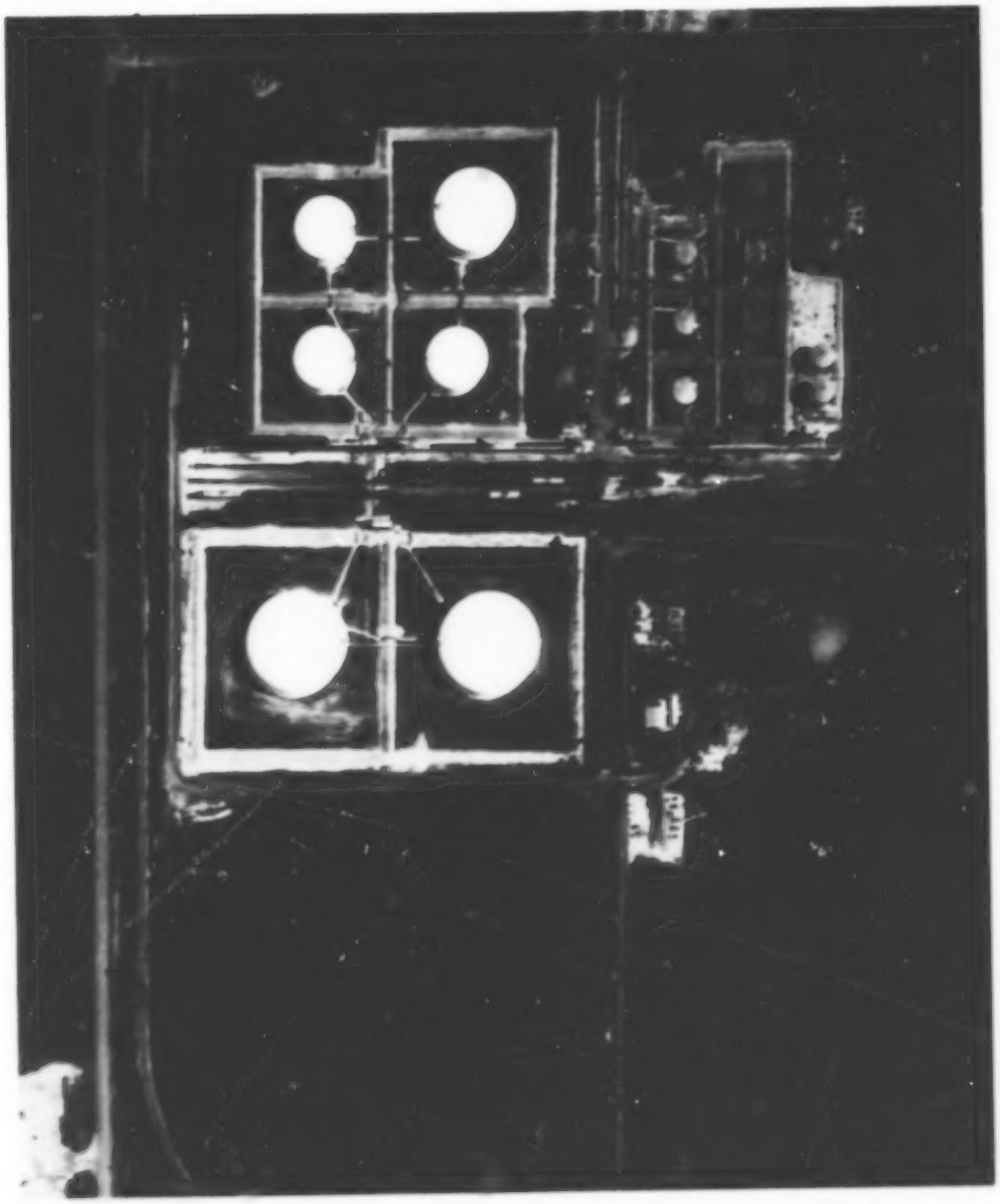

Figure 42. Engineered drainage posing a threat to an adjacent creek.

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